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Teachers' competence in the use of technology in teaching and learning mathematics in two rural schools

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Mathematics is one of the key subjects in the South African schooling system. Improving mathematics learning is an ongoing concern especially in rural schools. Rural schools are expected to be equipped with educational technology tools and schooling communities are concerned about the extent to which these tools are used to improve mathematics teaching and learning. There is a need for appropriate use of educational technology tools if they are to have a positive influence in the teaching and learning environment. This study explored the use of technology tools in the teaching and learning of mathematics in Grades 10–12 in two rural schools in Limpopo. The study was qualitative and employed semi-structured interviews and observations as the main data collection methods. Teachers and learners were used as research subjects. Findings are that teacher-centred pedagogical practices influenced how teachers used educational technology in mathematics lessons in the two schools. As a result, the study revealed that teachers' pedagogical competence contributed to how the technology was used in the mathematics teaching and learning environment. This research shed light on teacher professional development needs on the use of technology in Mathematics as a subject in rural schools.

Contribution: Continuous professional development programmes focusing on effective pedagogical use of technology in mathematics can contribute to better teaching and learning of mathematics in rural schools.

Keywords: pedagogical practices; TPACK; teachers' competence; mathematics teaching; rural schools.

Introduction

The use of technology has the potential to improve the teaching and learning of mathematics, leading to gains in higher-order thinking skills (Wenglinsky, 1998) as well as student achievement and self-efficacy (Lin, 2008). In South African schooling, the mathematics curriculum in Grades 10 to 12 is split into two forms. These are Mathematics and Mathematical Literacy. Learners must choose between these two forms. Most of the learners who register for pure mathematics do not perform well (DBE, 2015). This poor performance was seen in the analysis of Mathematics results in the Annual National Assessment (ANA) tests for Grades 3, 6, and 9 and the Grade 12 final-year results (DBE, 2014, 2015). The ANA analysis showed that 35% of learners in Grade 6 and 3% of learners in Grade 9 achieved 50% or more. However, the ANA tests have since been suspended due to teachers' unions' dissatisfaction in how the tests were conducted. The Grade 12 analysis showed that 53.5% of the learners achieved 30% or more.

Technologies are tools that offer possibilities for new approaches to teaching and learning as well as encourage and sustain learners' attention in mathematics (Stoilescu, 2015). Some technological tools are laptops, smartphones, calculators and desktop computers. In mathematics, technologies provide learners with opportunities to simulate a variety of complex scenarios and processes, visualise and explore mathematical content, and connect dynamic notations, linked representations and operations with symbols (Baya'a & Daher, 2013; Thorvaldsen, Vavik & Salomon, 2012). Technologies also have the potential to allow learners to explore and reach an understanding of mathematics concepts (Agyei & Voogt, 2011). Noor-Ul-Amin (2013) further indicated that the appropriate use of technology influences how mathematics is taught and enables interaction of teachers with learners, parents, peers, colleagues, and the global society. The above-mentioned approaches promote higher-order thinking skills, and better problem-solving strategies, which are the skills needed in mathematics teaching and learning (Albaladejo et al., 2015).

The foregoing paragraph demonstrates that the use of technology is believed to enhance learners' learning. However, successful outcomes depend more on how the teacher uses the technology in the classroom. Thus, teachers' competence in the use of technology in the teaching and learning of mathematics is one of the important factors that shape technology-mediated teaching and learning. These factors are themselves most often shaped by the institutions and classroom conditions (Law & Chow, 2008). In South Africa most rural schools acquire technological tools through donations (Botha et al., 2017; Isaacs, 2007). The Department of Basic Education (DBE, 2017) defines rural schools as formal institutions found in farms and traditional areas characterised by low population density, low levels of economic activity and low levels of infrastructure. Teachers in rural schools encounter different challenges compared to those in schools not found in rural areas (Phiri & Mahwai, 2014). The challenges include among others lack of technological resources for all the teachers. This compels teachers to share technology, and this can result in lack of time and freedom to experiment with technology by teachers. These mentioned studies of the use of technology in rural contexts focused on the use of technology generally in teaching and learning and not specifically in mathematics teaching and learning. Therefore, this qualitative study aims to explore rural teachers' competence and pedagogical practices around their use of technology in mathematics teaching and learning. A few studies were conducted on teachers' competence and pedagogical practices around their use of technology to improve mathematics teaching and learning in rural schools (Graham et al., 2021; Sall et al., 2020). Thus, exploring rural teachers' competence and pedagogical practices around their use of technology in mathematics will assist to develop strategies that can enable these teachers to use the technology to improve mathematics teaching and learning. The following research question was investigated in this study:

> What are mathematics teachers' competences in the use of technology in teaching in rural schools?

Literature review

The use of technology in teaching and learning requires new competences from teachers. Teachers should be able to select the appropriate technological tools out of a wide range of available tools and use them to improve teaching and learning (Westera, 2001). In this study teachers' competence pertains to teachers' ability to develop activities that will ensure efficiency and effectiveness of the use of technology in mathematics teaching and learning (Suárez-Rodríguez et al., 2018). In the context of this study, various literatures were reviewed to explore more about teachers' competence and pedagogical practices around their effective use of technology generally and specifically in mathematics teaching and learning.

Teachers' competence in the use of technology in teaching and learning

The United Nations Educational, Scientific and Cultural Organization (UNESCO 2011) developed an Information and Communication Technology (ICT) competence framework for teachers (ICT–CFT). The aim of developing the framework was to help countries to develop their national teacher ICT competence policies and standards. The purpose of this ICT–CFT was to equip teachers with teaching methods that are appropriate for an evolving knowledge society. In this framework UNESCO (2011) emphasises that successful educational technology use in the classroom will depend on the ability of teachers to structure the learning environment in new ways, to merge new technology with a new pedagogy, to develop socially active classrooms, encouraging cooperative interaction, collaborative learning, and group work.

This ICT–CTF is a guideline for countries to develop their teacher training programmes on the use of ICT in teaching and learning. Based on the UNESCO ICT–CTF, South Africa developed its own ICT in education competence framework (Department of Education [DoE], 2007). The intention of the framework was to develop teachers' use of educational technology in teaching to promote learners' critical thinking, informed decision-making, higher-order thinking skills and collaborative and experiential learning (DoE, 2007). The South African ICT in education competence framework includes both technical ICT competence and pedagogical ICT competence. Technological competence refers to skills, knowledge and attitudes in manipulating the different technological devices. Pedagogical competence refers to skills, knowledge and attitudes to use technology effectively in teaching. These two aspects are important in guiding teachers on effective use of technology in teaching and learning. Conducted studies demonstrated that pedagogical and technological competences contribute to effective use of technology in teaching and learning (Chou et al., 2018; Li, Yamaguchi, & Takada, 2018).

As a way of addressing the above-mentioned gap in the South African competence framework, Tarling and Ng'ambi (2016) developed a framework for finding changes undergone by teachers when they use technology in their classroom. This was because teachers were not using the technology despite attending several professional developments. Tarling and Ng'ambi mapped teachers' technological competence to pedagogical competence in determining a trajectory followed by teachers in their change journey. Technological competence was defined as the knowledge of the teacher about affordances of technology. Pedagogical competence was defined using different pedagogical approaches and ranking them on the revised Bloom's taxonomy (Anderson & Krathwohl, 2001). The revised Bloom's taxonomy is made up of the following levels: remembering, understanding, applying, analysing, evaluating and creating. Remembering, understanding and applying support low-level pedagogical approaches while analysing, evaluating and creating support high-level pedagogical approaches (Anderson & Krathwohl, 2001). Low-level pedagogical approaches involve the teacher controlling how content is disseminated in the classroom and testing whether the learners are able to retain the disseminated content (Anderson & Krathwohl, 2001). High-level pedagogical approaches involve the teacher acting as a guide in disseminating content in the classroom and testing whether the learners can use the disseminated content to solve problems they experience in their everyday lives.

Tarling and Ng'ambi (2016) found that most of the teachers' use of technology was consistent with pedagogical approaches that were rated on the low level of the Bloom's taxonomy. The framework can assist in coming up with professional development that will address teachers' changes when using the technology. However, like the South African competence framework, the framework is made for teachers in general with no specific adaptation to the different school levels and subjects. The same technology may offer different affordances to different subjects.

Teachers' competence in the use of technology in Mathematics

Educational technologies provide opportunities to access an abundance of information using multiple information resources and to view information from multiple perspectives, thus fostering the authenticity of the learning environment (Drijvers et al., 2016, 2019). Through simulation programmes, abstract concepts can be made more practical and accessible to all learners with different learning styles (Yeo, 2020). However, all these opportunities do not occur automatically. The way teachers implement and use technology in mathematics is important in ensuring that the technology is used to improve teaching and learning. This implies that teachers' pedagogical practices will be affected, together with teachers' and learners' roles and their classroom practices.

There are numerous studies focusing on teachers' effectiveness in the use of educational technologies conducted worldwide. Law and Chow (2008) indicated that teachers' technological competence is a predictor of effective technology use in the class. A more recent study by Chou et al. (2018) found that teachers' technological competence was one of the factors that contributed to teachers' effective use of technology. This demonstrated that teachers' technological competence is important in effective use of technology in teaching. The two mentioned studies are quantitative. Also, these studies were not conducted in a rural schools context. The findings by Mensah (2017) revealed that Ghanaian mathematics teachers did not use technology in their classrooms despite being trained on technological skills. Mensah concluded that these teachers did not use the technology for instructional delivery because they lack competence in their use. Suárez-Rodríguez et al. (2018) developed an ICT integration model that focused on teachers' competence in the use of technology, particularly in mathematics teaching. The model revealed that when technological competence was linked to pedagogical competence, a predictive relationship of teachers' uses of technology in teaching and learning resulted. This implies that technological competence and pedagogical competence are key factors in teachers' effective use of technology in teaching. However, the model was never tested in empirical studies.

Graham et al. (2021) found that most South African mathematics teachers used technologies like computers, the internet, Microsoft Office Word and Excel for personal use, but these tools were not used very often with learners in the classroom. Graham et al. (2021) concluded that teachers lacked skill in pedagogical use of technology in teaching mathematics. This implies that teachers were not able to come up with innovative ideas for using technology in mathematics teaching. A qualitative study by Saal et al. (2020) found that teachers' use of technology for teaching mathematics was not easy due to teachers' limited technological knowledge. The study was conducted in two poor communities in South Africa. Saal et al. recommended continuous professional development on how to use technology in the classroom in such a way that the use of technology will ensure improved learning outcomes. However, Saal et al.'s study did not indicate how the professional development should be implemented.

The literature review showed that technological and pedagogical competences are essential aspects of teachers' effective and efficient use of technology in teaching. Also, most of the studies demonstrate that teachers lack either technological or pedagogical competence in the use of technology in mathematics teaching and learning. None of the mathematics studies showed that teachers lacked mathematical competence. The literature further showed that few studies were conducted in South Africa focusing on teachers' competence in the use of technology in rural schools. Almost all the studies were conducted using a quantitative approach except for the study conducted by Saal et al. (2020). However, Saal et al. focused on Grade 5 mathematics teachers whereas in this study the focus was on Grades 10 to 12 mathematics teachers. What follows is a discussion of the theoretical framework that guided the study.

The TPACK framework

In this article the TPACK framework allowed me to make sense of how teachers' competences influence the decisions they make while using technology in mathematics teaching. TPACK entails the knowledge of using technology in a specific subject and implementing pedagogical strategies in the context of teaching. TPACK was proposed by Mishra and Koehler (2006) and is derived from Shulman's (1986) pedagogical content knowledge (PCK) model. Mishra and Koehler argued that for effective use of technology, teachers should understand how knowledge of technology, pedagogy and content interact in teaching. As indicated above teachers' competence in the use of technology is indicated by the sets of skills, attitude, knowledge and practices that teachers display when using technology in teaching. All the above-mentioned competences are entailed in the TPACK framework.

TPACK consists of three main components: Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). The interaction between these three components results in Technological Pedagogical Knowledge (TPK), PCK and Technological Content Knowledge (TCK), while TPACK is the intersection of TPK, PCK and TCK. The following sections provide details on each of the domains of the TPACK framework to establish their individual elements and characteristics.

Content Knowledge

Content Knowledge is about the subject matter knowledge the teacher possesses (Koehler et al., 2013). Koehler et al. (2013) point out that teachers must know and understand the subject they teach. In this study, Niss and Jensen's (2002) mathematical competencies are used to explain teachers' procedural and conceptual knowledge. The competencies include mathematical thinking, modelling, reasoning, representing, symbol and formalism and communicating. These competencies enable the teacher to clearly introduce mathematics concepts and learning goals in a lesson.

Pedagogical Knowledge

Pedagogical Knowledge is deep knowledge about the process and practice or methods of teaching and learning (Koehler et al., 2013). A teacher with a deep PK understands how learners construct knowledge and acquire skills, develop habits of mind and a positive disposition towards learning (Koehler et al., 2013). As this study focused on mathematics, this implies that the teacher should be able to use teaching and learning strategies that will foster effective and meaningful learning of mathematics.

Technological Knowledge

Technological Knowledge is the knowledge, skills and values that enable a person to accomplish a variety of different tasks and develop different ways of accomplishing a given task using technological tools (Koehler et al., 2013). This implies that the teacher should be able to operate the technology they are using in the classroom.

Technological Content Knowledge

Technological Content Knowledge is an understanding of the way in which technology and subject content constrain and influence each other (Koehler et al., 2013). Teachers need to know technologies that would be appropriate in helping them to represent learning content in an interesting and meaningful way to learners. As this study focused on mathematics, this implies that the teacher should be able to use the technology to represent mathematics concepts effectively.

Technological Pedagogical Knowledge

Technological Pedagogical Knowledge is an understanding of how teaching and learning can change when different technologies are used in specific ways (Koehler et al., 2013). This study is focused on mathematics. Thus, the above statement implies that TPK can enable teachers to use the technology to engage the learners in mathematics activities.

Pedagogical Content Knowledge

Pedagogical Content Knowledge is an understanding of how particular topics, problems, or issues are organised, represented, and adapted to the diverse interest and abilities of learners and presented for instruction (Koehler et al., 2013). This is like Shulman's (1986) idea of knowledge of pedagogy that is required to teach content. Teachers with deep PCK can transform the subject matter and make it accessible to all learners in their classrooms. This will arouse and stimulate learners' interest in solving mathematics problems (Lee et al., 2018).

Technological Pedagogical Content Knowledge

TPACK is the intersection of TK, CK and PK components and is the heart of good teaching with technology. Teachers with deep TPACK can represent mathematical ideas using technology, use pedagogies that foreground the constructive use of technology to solve mathematical problems and use technology to build on existing mathematics knowledge (Guerrero, 2010; Stoilescu, 2015). Teachers should be able to use appropriate technology for the mathematics concepts they are going to present and use the technology to implement effective teaching and learning strategies.

TPACK has been used in mathematics teachers' professional development programmes (Kafyulilo et al., 2015). Kafyulilo et al. (2015) found that teachers' TPACK development impacted positively on their classroom practices and learners' learning. The TPACK framework has also been used in secondary data analysis to measure mathematics teachers' TPACK levels (Leendertz et al., 2013). Leendertz et al. (2013) found a significant association between teachers' TPACK level, impact of ICT uses in mathematics, teachers' practices, teachers' confidence, and barriers to ICT use in mathematics teaching and learning. De Freitas and Spangenberg (2019) used a questionnaire to investigate 93 mathematics teachers' TPACK levels, sampled 10 from the 93 teachers and used an interview schedule to investigate the barriers they encountered when using technology in teaching. The findings revealed that teachers reported a high level of CK, PK and PCK. It was recommended that the teachers need professional development that will develop their knowledge of TPK, TCK and TPACK. Guerrero (2010) found that TPK played a prominent role in the TPACK components in mathematics. A study by Stoilescu (2015) found that teachers' TPACK contributed to how they used technology in their classrooms. Teachers were able to redesign their pedagogical practices and used the technology as learning support for the learners in learner-centred teaching strategies (Stoilescu, 2015). However, an extensive review of the relevant literature failed to produce any study on the use of the TPACK framework to explore mathematics teachers' competence in the use of technology in South African rural schools.

TPACK was criticised for a lack of clear, universally accepted definitions of the core constructs, and the blurry boundaries between them (Angeli & Valanides, 2009; Archambault & Barnett, 2010; Jimoyiannis, 2010). In addressing these identified weaknesses, Cox and Graham (2009) conducted a conceptual analysis of the TPACK framework, which resulted in a more precise TPACK definition that highlighted the unique features of each construct.

Research methodology

The study used a qualitative approach to investigate teachers' use of educational technology in mathematics in the two schools. A qualitative approach allowed me to observe and interview participants in a natural setting and enabled me to develop a level of detail from close involvement in the actual experience (Cohen et al., 2017). Thus, participants' subjective meaning is of utmost importance. Two teachers were interviewed and observed in their classroom environment. Gaining a rich and deep understanding of teachers' experiences, meaning, and perspectives and capturing their voices and conversations, was of utmost importance in this approach. In circumventing bias, I used two different data collecting techniques and member checking for the interview transcript was done.

Participants and sampling

Two schools were identified in Mopani District of Limpopo. The schools were purposefully identified to participate in the study. I asked the ICT district coordinator about schools that were implementing educational technologies in their teaching and learning and were in rural communities. Thus, the schools were handpicked based on the information I received from the ICT district coordinator. I was therefore limited to two schools. One teacher from each school participated in the study. The two participants are referred to as Participant A and Participant B. Both participants were male.

Data collection techniques

Two data collection were employed in this study. The semi-structured interviews were used in this study to initiate a conversation with teacher participants about their experiences, competences, and pedagogical practices in the use of educational technology generally, and in mathematics teaching specifically. The interview schedule was piloted with teachers who were not involved in the study to ensure consistency. Also, in instances where a participant responded with one word, a probing question followed. The information collected from the teachers' interviews gave insights into teachers' competence and pedagogical practices in their effective use of educational technology. The other data collection technique used was observation. The observation was used to gain first-hand experience of the interactions among learners, the teacher, and the technological tools in the classroom environment. A video recorder was used to capture the observed lessons and notes were also taken during the observation. Table 1 was used to transcribe the data from the recorded lessons and the notes taken during the observation. Participant A's observed lesson was on coordinate geometry while Participant B's observed lesson was on sequences and series.

Data analysis

The interview data were transcribed verbatim. Member checking was conducted with interviewees after transcribing the data. I deductively coded both the interview and observation transcripts. Table 1 was used to develop observation codes. Codes were compared to see the emerging patterns. Similar patterns were grouped into categories. The categories were grouped under three themes that were based on the theoretical framework. Participants' subjective meaning of their accounts in relation to the study ensured that developed themes are consistent and coherent. The three themes are technological competence, pedagogical competence and mathematical competence. Technological competence focused on teachers' skills, knowledge and attitudes of manipulating the technological devices and the ability of teachers to identify the teaching and learning opportunities created by the technology. The focus was informed by two components of the TPACK framework which are TK and TCK. Pedagogical competence focused on teaching and learning strategies and the essential use of the technology by the teachers. The teaching and learning strategies were differentiated into teacher-centred and learner-centred strategies (Al-Zu'be, 2013). Teacher-centred strategies are strategies wherein the teacher is the central figure in the teaching and learning environment and there is very little or no interaction among the learners. Learner-centred strategies involve a high interaction among the learners and little interaction between the teacher and the learners in the teaching and learning environment. The focus of pedagogical competence was informed by two other components of the TPACK framework which are TPK and PK. Mathematical competence focused on teachers' procedural and conceptual knowledge. The focus was informed by one component of the TPACK framework which is CK and Niss and Jensen's (2002) mathematical competencies. These themes are used as sub-headings in the findings section, and they assisted me in organising and structuring my findings section.

TABLE 1: A guideline to transcribing observations.

Type of technology used	Technology user	Activities in which the technology is used	How does the technology support the instructional strategies?	How does the technology support learning?
Laptop	Teacher	The teacher is presenting maths concepts	Saves the teacher's time of writing	Keeps learners focused on the presentation

Ethical considerations

The research was granted ethical clearance by the overseeing university. The overseeing provincial department of education granted permission to conduct the research. The circuit management and the principals of the two schools granted permission for the study to be carried out. Informed consent was obtained from all individual participants included in the study and parents of learner participants.

Findings

In this section the findings obtained through interviews and observations conducted on teachers' competence in their use of technology in mathematics teaching and learning are presented. As indicated in the data analysis section, the findings are based on the TPACK framework and divided into three parts: teachers' technological competence, mathematics competence and pedagogical competence. Technological competence focused on technology skills and teaching and learning opportunities created by the technology. Mathematics competence focused on teachers' procedural and conceptual knowledge of mathematics. Pedagogical competence focused on teaching and learning strategies used and essential use of the technology in the classroom. The findings relating to Participant A competence will be presented first, followed by those relating Participant B.

Participant A competence

Participant A was a 26-year-old male teacher from school A. He had three years teaching experience and a Bachelor of Education degree qualification in Mathematics and Physical Science. He taught Grades 11 and 12 Mathematics and Grade 10 Physical Science classes. During his pre-service teacher training programme, he had been trained in the use educational technology in teaching and learning. However, he never presented any lesson using educational technology tools during this training.

Technological competence

Participant A owned a desktop computer and a smartphone. He used laptops in his classroom which belonged to the school. The laptops were not enough for each learner; thus, each laptop was shared by a maximum of six learners. Participant A demonstrated knowledge of how to use technologies in his classroom. In his instructions to learners while using laptops he used correct technology terms appropriate to the type of technology used. He also helped learners to do some troubleshooting tasks like increasing the screen brightness on some of the laptops that were not appropriately set. He also gave step-by-step instructions to learners on how to open the application program that they were going to work with. The steps were straightforward, clear, and easy to follow. This is how the instructions were given:

> 'There is a button for switching on the power, press the button on [*a chuckle from learners reacting to their teacher's instruction*] and wait for the computer to be on. If they [*laptops*] are on, right down on the desktop you are going to look for an application which says … [*identified some students challenges with screen settings*]. If your computer screen is dark, increase the brightness. Press the Fn function at the bottom of the keyboard and hold. Then press the F9 function at the top of your keyboard. Let's look for a program on the desktop. It says Encarta premium.' (Participant A, 26 years, male, teacher)

Although the lesson was about mathematics, Participant A incorporated technical skills in his lesson. The above quote confirms this. Later during the lesson he switched from Encarta to Vodacom mathematics programs, which some laptops could not open. Although he had an assistant, he physically went to every laptop that was problematic to do some troubleshooting. He considered himself an expert in computer technology.

Thus, by incorporating the technical skills, he was equipping the learners with some of the skills they would need in future when they pursue their higher education studies. This was confirmed by Participant's A view during the follow-up interview after observing his lesson:

> 'The reason for my laptop usage was to check if learners are able to use laptops and the lesson was maths related. So, I decided that I can have those laptops and let learners use the laptops themselves.' (Participant A, 26 years, male, teacher)

This indicated that Participant A was aware that both teachers' and learners' technological skills were important in the use of educational technology in the classroom. Hence, he used laptops to reinforce learners' technological skills. However technological skill alone is not sufficient to equip teachers with technological competence (Mensah, 2017).

Further on Participant A demonstrated knowledge of how concepts could be presented in a simpler way using technological tools. He viewed technologies as some of the tools that could help learners to understand concepts better. He noted:

> 'Looking at the calculator it helps learners to get the answers easily. We have this new Casio calculator they can even punch in the formula, so it makes life easier for them.' (Participant A, 26 years, male, teacher)

However, he was not able to identify the teaching and learning opportunities created by the laptops. This is consistent with Tarling and Ng'ambi's (2016) study and it demonstrated that Participant's A technological competence was at a low level.

Mathematical competence

During my observation of Participant A's lesson, I witnessed how he used mathematical language to explain mathematics concepts to the learners. The language was correct and appropriate to the concepts he was teaching in his classroom. He introduced the topic for the lesson – coordinate geometry. He started his lesson by asking a learner to read from the laptop on colinear points. After the learner had finished reading about the concept, he explained the concepts using his own words. He later used the concept of colinear to show non-colinear points. He proceeded to link points with lines and line segments. In this instance he showed his mathematical thinking competency. He used what was known to introduce and explain a new concept to the learners.

Participant A moved on to show the relationship between lines. Lastly, lines were used to construct geometric structures on a Cartesian plane. In this instance Participant A demonstrated several competencies as indicated in Figure 1. He also used the chalkboard to expand and explain some concepts which he considered difficult for the learners. In this instance he demonstrated his mathematics representation competency. Confirmation of learners' understanding of the lesson was seen in their overwhelming positive response to questions related to the topic that had been presented. However, he used low-level questions as they required the learners to merely reproduce information.

The above discussion demonstrated that Participant's A mathematical competence was not at a low level. He was able to use the different mathematical competencies to explain coordinate geometry concepts to the learners.

Pedagogical competence

Participant A demonstrated lack of knowledge in linking pedagogical and technological skills. This was evidenced in how he expressed his ideas about the use of technology in teaching and learning. He explained about what made him decide to use a technological tool in his classroom:

> 'It is the content you will be dealing with. Somewhere they need to use a calculator because they will be calculating numbers that you cannot do with your mind and then if it is a presentation lesson then you will need a computer so that you can present whatever you will be presenting to them. And suppose I want to make them worksheets, then that is when I go to a printer and print copies.' (Participant A, 26 years, male, teacher)

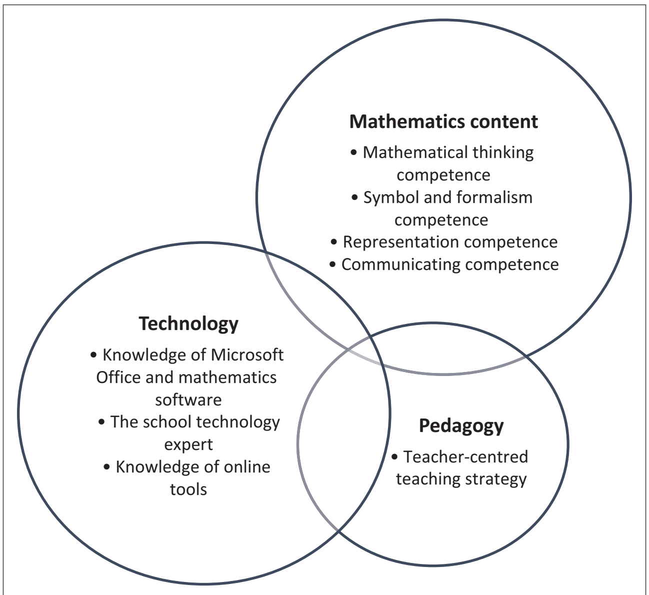

FIGURE 1: Participant A's use of educational technologies in mathematics based on the TPACK framework.

Although he was guided by content on which technologies to use, the technology used was supposed to help learners to grasp concepts in a meaningful way. From his explanation, a calculator was used to alleviate learners' routine work. The computer was used to present a lesson. He should have identified the potentials and constraints of technology use in his classroom; if he had done so, he would have been using the tools for the benefit of the learners.

Overall, the findings represented in Figure 1 indicate that Participant A's competence in the use of laptops in mathematics teaching was at a low level despite having the technical skills of operating the laptops. Participant A's low level of pedagogical competence was also a major issue contributing to how the laptops were used in the lesson. Participant A demonstrated a strong mathematical competence which did not contribute competence in the use of laptops in mathematics teaching. This is consistent with TPACK studies which found that the PK component in the TPACK framework was a contributing factor to effective use of technology in the classroom (Guerrero, 2010; Kafyulilo et al., 2015; Leendertz et al., 2013). Another possible explanation could be that approximately six learners were sharing one laptop in his class. This was due to the school's socio-economic status.

Participant B competence

Participant B was a 41-year-old male teacher from school B. He had 19 years teaching experience. His highest qualification was an Advanced Certificate in Education (ACE) in Mathematics. He taught Mathematics in Grades 11 and 12. He was also the Head of Department (HOD) for the mathematics department. Participant B had acquired the skills of using technology in teaching and learning when he was studying for his ACE qualification. One of the modules he took involved the use of educational technology in teaching and learning. However, he never used the educational technology tools in the classroom during his study of an ACE qualification.

Technological competence

Participants B owned a desktop computer and a smartphone. However, he used a laptop in his classroom which belonged to the school. The place where the computers were stored was not conducive for him to work with the learners. Thus, he used the laptop in the science laboratory, which was used as his classroom. Learners went to his classroom and found the laptop and data projector ready for the lesson to begin. Also, different grades could move freely in and out of his room.

He indicated that by using the computer for a long time, he had gained the confidence to use it in his classroom.

He mentioned that he had been using a computer for almost 10 years. However, during my observation of his lesson, I could only see a handful of his skills demonstrated. He connected the laptop to the data projector and did not struggle to get the laptop screen projected onto the larger screen. Then he opened a folder containing the mathematics concepts he was going to discuss with the learners in the classroom. The concepts were in PDF format. He presented the concepts without any adjustment. The format did not affect his presentation because he was presenting mathematics sentences, which are usually loaded with symbols and formulae. I asked him during the post-observation interview about using the PDF document for presentation and his response was that 'it saves time of rewriting the work'. From his response it was evident that he was not aware that there are a lot of limitations when using a PDF document as a presentation tool. The school did not have a special program to edit PDF files. Thus, he would not have been able to edit any part of the document. All that he did with the laptop during the lesson was to scroll up and down.

Participant B further mentioned that they used to have a collaboration project funded by a mining company. Four secondary schools in their circuit had been identified to participate in this project, with his school as the hub. That was the main reason why the school had been given a smart board as a donation. They used their smart board to broadcast mathematics lessons to all schools involved in the project. Participant B had been the coordinator of the project. However, the project could not be sustained owing to a lack of financial resources. Thus, the smart board was no longer used for its purpose; it was now used as a projection screen for the data projector. The above discussion demonstrates that Participant B's technological competence was at a low level.

Mathematical competence

During my observation of his lesson, I noticed how Participant B pursued learners' conceptual gaps through questioning. He started by showing learners the different formulae that were used in sequences and series. This indicated his competencies in mathematics symbol and formalism and mathematics representation. He then explained what different variables represented in those formulae. In this case Participant B demonstrated competence in mathematical communication and mathematics representation. Then he moved from procedural mathematics knowledge to conceptual knowledge of mathematics. He showed learners the inappropriateness of fractions and negative numbers in determining terms' positions in a sequence. In this instance Participant B demonstrated competence in mathematical thinking, mathematical reasoning, mathematical problem tackling and representation competence. He also demonstrated knowledge of understanding the deductive nature of mathematics. This was seen in how he showed learners the connection between different mathematics concepts. While showing learners how to use a series to determine terms in a sequence, a question was raised by one learner. The learner wanted to know how he could use a series formula if one term in a sequence was unknown.

The explanation presented in Figure 2 shows that Participant B first used the formula for a series to determine term 6 in the sequence. However, the last term was unknown; thus he used both the sum and the general term formula of the sequence to determine the term. In this explanation he demonstrated mathematical thinking competency, symbolism and formalism competency, mathematical representation competency and problem-solving competency.

Later during my visit at this school, I witnessed Participant B assisting another colleague with mathematics concepts issues. This indicated that his colleague trusted his mathematics conceptual knowledge and would draw on this knowledge as a way of learning. However, teaching is a very complex process, and one cannot apply linear reasoning. Having a high content knowledge in mathematics does not guarantee the effective teaching of learners.

Pedagogical competence

When I arrived in Participant's B class to observe his lesson, I found the laptop and the data projector ready. The teaching time for the next class had not yet started, and he had a free period. When the period started learners came from their classroom to the mathematics laboratory for their mathematics lesson. He was teaching a Grade 12 Mathematics lesson. When all the learners were in the laboratory, he greeted them and introduced the topic they were going to discuss.

Participant B adopted a teacher-centred approach when using the laptop in his classroom. Learners were passive participants in the learning environment (Al-Zu'be, 2013). However, he saw the computer as helping him to improve his teaching. He pointed out:

> 'Normally I display my lessons on a screen so that it become easier and time saving to copy activities and whatever, it is simply displayed. So, I think my teaching is improved. '(Participant B, 41 years, male, teacher)

Projecting the lesson for the learners does not improve teaching. Most of the learners in his class did not volunteer

FIGURE 2: Participant B's algorithm response to a learner's question.

to respond to his questions. Teaching is improved when learners are actively involved in the projected lessons (Al-Zu'be, 2013).

He further indicated how this engagement had contributed to mathematics learning. However, the engagement involved a handful of learners solving problems on the chalkboard individually as indicated in Figure 3. Each learner had a turn to work on the chalkboard provided they volunteered by raising their hands. Participant B was guiding the process by asking other learners if the volunteer learner was on the right track. As soon as a fellow learner realised that the volunteer learner had made a mistake, their chance to participate started. They would go to the front, take away the chalk from the learner who was solving the problem, correct the mistake and complete solving the problem without any verbal communication. Participant B gave feedback when there were no more learners at the chalkboard.

The learner in Figure 3 was solving a series problem. She wrote the formula and substituted values on the formula. The learner then proceeded to use a calculator to operate the values. Her facial expression was stunned after she got the answer from the calculator. She was reflecting on her formulae as well as substitution. While she was reflecting another learner, who had identified the mistake, came to the chalkboard, grabbed the chalk, rectified the mistake, and completed the solution to the problem. All these activities occurred without the two learners communicating with each other. This did not come as a surprise because communication in the classroom was facilitated by Participant B asking questions and learners responding to his questions.

This was made possible because content was projected onto the screen and the chalkboard afforded more space for the learners. Also, learners had more time to solve the problems because they were not copying the problems, as they were projected onto the screen. However, learners were restricted to working in the chalkboard space only. They could not work from the laptop, as it was the only one being used.

FIGURE 3: A learner working on a chalkboard space.

Trying to allow learners to use the laptop was going to create more work in classroom management. Besides, Participant B had not taught learners how to operate the laptop.

Although Participant B had more space on the chalkboard because of the data projector, moving from the chalkboard to the laptop created a lot of movement for Participant B which at times distracted the learners. He did not realise the opportunity offered by the overhead projector for group discussion activities. What is more, the lesson's aim was to dispel learners' misconceptions on arithmetic, geometric and quadratic sequences. It was also a revision lesson and learners had acquired some of the formulae and procedures for solving problems related to mathematics sequences.

The laptop gave him more time and space to enable learners to demonstrate their work to other learners. However, the school's socio-economic status dictated the tools he could use in his classroom environment. The way he used the laptop was to compensate for the resources the school did not have.

Overall, the findings represented in Figure 4 show that Participant B's mathematical competence was at a higher level than either his technology competence or his pedagogical competence. The mathematical competence did not have any influence on his use of technology in mathematics teaching. He lacked strategies of using educational technologies effectively in his class. Although he had completed a course on the use of technology in mathematics teaching, he had never been taken to a class where he could apply the theoretical knowledge gained in that course. This is consistent with the Graham et al. (2021) and Saal et al. (2020) studies which demonstrated that teachers' professional development contributes to teachers'

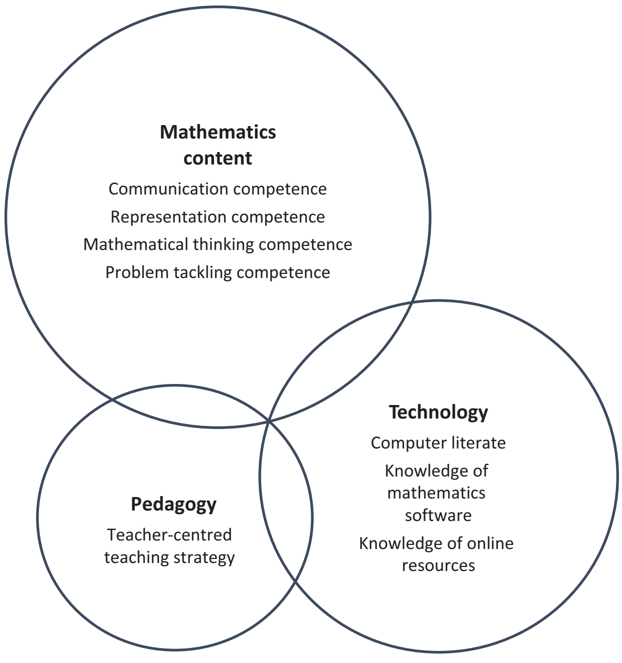

FIGURE 4: Participant B's use of educational technology in mathematics based on the TPACK framework.

competences and the ways in which they use technology in their teaching environment. Another possible explanation could be that Participant B was using one laptop for the whole class. The laptop was the only tool available to him because of the school's socio-economic status.

Discussion

The study used the TPACK framework to explore teachers' competence in their use of educational technology in mathematics teaching. The study found that teachers' pedagogical competence, technological competence and the schools' socio-economic status constrained teachers' effective use of technology in the classroom. The teachers displayed some technical skills in operating the laptops. This could have encouraged the participants to use the laptops in their classrooms (Chou et al., 2019). However, technological skills alone do not account for effective technology usage in teaching (Kafyulilo et al., 2015). Thus, teachers lacked the competence in choosing appropriate technology that will assist them to present mathematics concepts in an interesting and meaningful way to the learners. This is consistent with findings from Tarling and Ng'ambi (2016) and Li et al. (2018).

South African teachers were supposed to be using educational technology to develop learners' critical thinking, informed decision-making, higher-order thinking skills and collaborative and experiential learning (DoE, 2007). These competences can be developed if teachers use the technology to support learner-centred strategies (Stoilescu, 2015). Learners will be actively engaged in the learning environment (Al-Zu'be, 2013). However, teachers in the two investigated schools were never trained by the DoE on the use of technology in teaching and learning. Schools in rural areas do not have enough resources to enable teacher training on the use of technology in teaching and learning. Thus, it can be posited that the South African ICT in education competence framework is far from being realised in these schools.

Limitations

The fact that the study focused on mathematics classrooms in two schools means conclusions cannot be generalised beyond these classrooms. However, teachers and learners in similar contexts to those in my study may benefit from my study findings if they put them into practice. In both schools, the teachers used laptops in their classrooms. Thus, the findings are limited to teachers' laptop usage. Also, the aim of the study was not to make a generalisations but to develop ideas for further studies.

Conclusion

The findings of this research demonstrated that South African mathematics teachers are struggling to use technology effectively in teaching due to low levels of technological and pedagogical competence. Thus, a teacher professional development programme is recommended to enhance teachers' technological and pedagogical competence in the use of technology in mathematics teaching. In developing teachers' technological and pedagogical competence, the programme should be conducted within schools and be teacher driven and not expert driven. Experts should model effective use of technology in mathematics using the schools' available technological resources. This will help teachers to see how others are using technologies based on their context.

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Author's contributions

M.M.M. declares that they are the sole author of this article.

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Data availability

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