



OPEN ACCESS

EDITED BY

Luiz Sanches Neto,
Federal University of Ceara, Brazil

REVIEWED BY

Neni Hermita,
Riau University, Indonesia
Xiaolei Ruan,
Anhui University, China
Abraham Gyamfi,
Akonten Appiah-Menka University of Skills
Training and Entrepreneurial Development,
Ghana

*CORRESPONDENCE

Medwin Sepadi
✉ medwin.sepadi@ul.ac.za

RECEIVED 19 December 2024

ACCEPTED 04 June 2025

PUBLISHED 02 July 2025

CITATION

Sepadi M, Kgaphola T and Molapo K (2025)
Teachers' understanding of technology usage
in rural schools.
Front. Educ. 10:1548457.
doi: 10.3389/feduc.2025.1548457

COPYRIGHT

© 2025 Sepadi, Kgaphola and Molapo. This is
an open-access article distributed under the
terms of the [Creative Commons Attribution
License \(CC BY\)](#). The use, distribution or
reproduction in other forums is permitted,
provided the original author(s) and the
copyright owner(s) are credited and that the
original publication in this journal is cited, in
accordance with accepted academic
practice. No use, distribution or reproduction
is permitted which does not comply with
these terms.

Teachers' understanding of technology usage in rural schools

Medwin Sepadi^{1*}, Tukiso Kgaphola¹ and Karabo Molapo²

¹University of Limpopo, Sovenga, South Africa, ²School of Interdisciplinary Research and Graduate Studies, College of Graduate Studies, University of South Africa, Pretoria, South Africa

This study aimed to examine rural teachers' understanding and implementation of technology integration in under-resourced South African schools. Using a qualitative single-case study design, the research employed semi-structured interviews and focus group discussions with four purposively sampled teachers, analyzed through the TPACK framework. Key findings revealed three critical challenges: (1) insufficient technological knowledge and training among educators, (2) severe resource limitations, including inadequate devices and unreliable infrastructure, and (3) systemic misalignment between available technologies and curriculum requirements. The study further identified how these barriers interact to constrain effective pedagogical integration of technology. These findings have important implications for educational policy and practice, suggesting the need for: comprehensive professional development programs targeting technological-pedagogical skills; improved resource allocation and infrastructure support; and stronger alignment between technological tools and curricular objectives. The research contributes both empirical insights from a typically underrepresented rural context and practical recommendations for enhancing digital education in resource-constrained environments.

KEYWORDS

technology integration, rural education, teacher training, curriculum alignment, digital divide

1 Introduction

Technology integration in education has become increasingly prevalent, with schools worldwide incorporating various digital tools and resources into teaching and learning practices (Akram, 2022). However, the extent to which technology is effectively utilized, particularly in rural schools, remains a subject of ongoing inquiry. In the context of rural education, where access to resources and infrastructure may be limited, understanding teachers' perspectives on technology usage is crucial for informed decision-making and effective educational practice.

Research provides insights into the complexities of technology integration in educational settings, highlighting both the opportunities and challenges associated with its implementation (Tondeur et al., 2016; Hilton, 2016; Ly et al., 2024).

Studies have explored various factors influencing technology adoption, such as teachers' attitudes and beliefs, professional development opportunities, and organizational support structures (Lawrence and Tar, 2018). However, much of this research has focused on urban or suburban contexts, overlooking the distinct challenges faced by rural schools.

Moreover, the limited research specifically addressing technology usage in rural schools often highlights disparities in access and resources compared to their urban counterparts (Graves et al., 2021). While some studies have identified innovative strategies for overcoming these challenges, there remains a gap in understanding how teachers in rural schools conceptualize and utilize technology in their instructional practices. This knowledge gap inhibits the

development of targeted interventions and support mechanisms tailored to the unique needs of rural teachers (Kelley and Knowles, 2016).

Internationally, the digital divide remains a significant concern, accentuated in rural areas where access to technology, internet connectivity, and technical support are often lacking (Azionya and Nhedzi, 2021). Study by Ramnarain and Malope (2023) have highlighted disparities in technology access and usage between urban and rural schools, emphasizing the need for tailored interventions to bridge this gap. While initiatives such as one-to-one device programs and internet expansion projects have been implemented in various countries, the effectiveness and sustainability of these efforts in rural contexts require closer examination.

In Africa, where rural communities constitute a substantial portion of the population, the digital divide exacerbates existing educational inequalities (Krönke, 2020). Research by Ramnarain and Malope (2023) underscores the importance of understanding the socio-cultural dynamics shaping technology integration in African rural schools. Factors such as language diversity, cultural relevance, and community engagement emerge as crucial considerations in designing effective technology-enhanced pedagogies (Bower, 2017).

South Africa, initiatives like the Rural Education Access Program (REAP) have aimed to provide schools with ICT infrastructure and training. However, challenges related to infrastructure maintenance, teacher capacity building, and contextual relevance persist (Chigona, 2017). Similarly, in Nigeria, efforts to promote digital literacy in rural schools' face hurdles related to electricity supply, teacher training, and curriculum alignment (Luo, 2022). These cases underscore the need for localized strategies that account for diverse socio-economic and infrastructural realities.

The Lepelle Nkumpi Circuit in the Capricorn District presents an interesting case study for exploring the dynamics of technology integration in rural schools. Situated in a predominantly rural area, the schools within this circuit face unique challenges, including limited access to technology, inadequate infrastructure, and socioeconomic disparities among students (Masango et al., 2020). Despite these challenges, there is a growing recognition of the potential of technology to enhance teaching and learning experiences, improve educational outcomes, and bridge the digital divide in rural communities (Luo, 2022).

The motivation for this study stemmed from the need to address the gap in understanding teachers' perspectives on technology usage in rural schools, specifically within the context of the Lepelle Nkumpi Circuit. While existing literature provided valuable insights into technology integration in education, there is a paucity of research focusing on rural schools, particularly in South Africa (Padayachee, 2017).

This study aimed to explore teachers' understanding of technology usage in rural South African schools, identify key challenges (such as limited technological knowledge, inadequate training, resource shortages, and curriculum misalignment), and propose actionable recommendations to enhance technology integration, professional development, and collaborative support for equitable education.

2 Literature review

2.1 Digital technology integration in education: challenges and opportunities for teachers

Xu et al. (2025) provide a comprehensive analysis of the challenges and opportunities associated with technology integration in rural schools. Their study effectively highlights the acknowledgment among teachers of technology's potential benefits, such as heightened student engagement and improved access to educational resources (Xu et al., 2025). However, while the study identified significant barriers hindering effective integration, such as limited funding and insufficient professional development opportunities, it could benefit from a more in-depth exploration of potential solutions to address these challenges. Nonetheless, the study effectively underscored the complexity of technology adoption in rural educational contexts.

2.2 Rural teachers' perceptions on the use of technology

Anderson (2022) offers valuable insights into teachers' perceptions of technology usage in rural schools through qualitative research. The findings emphasized the importance of technology among educators while also revealing significant obstacles, such as infrastructure constraints and inadequate training, hindering seamless integration. However, the study could be further strengthened by exploring the impact of these perceptions on actual technology usage in teaching practices and considering the perspectives of other stakeholders, such as students and administrators.

2.3 Sustaining successful ICT integration in remote rural schools

Que (2021) contribute valuable insights into the diversity of technology integration strategies employed by teachers in rural schools through a comparative analysis. Their study underscored the importance of tailoring support mechanisms to address the unique challenges faced by educators in rural settings. However, while the study effectively recognized variations in approaches to technology usage, it could further explored the effectiveness and sustainability of these strategies over time, as well as their impact on student outcomes.

2.4 Technology integration professional development for rural teachers

Davis and Hall (2018) focus on the professional development needs of teachers in rural schools concerning technology integration. Their research highlighted a significant gap in training opportunities tailored to the specific needs of rural educators. While the study effectively identified that gap, it could benefitted from a deeper exploration of potential barriers to accessing professional development and the potential impact of tailored training programs on technology integration and teaching practices.

2.5 Exploring innovative approaches to technology integration in rural schools

Brown et al. (2019) explored innovative approaches to technology integration in rural schools, providing insights into successful strategies employed by educators to overcome challenges such as limited resources and infrastructure constraints. Their findings offered valuable guidance for future interventions aimed at promoting effective technology usage in rural educational settings. However, the study could be strengthened by considering potential scalability and sustainability of these innovative approaches, as well as their long-term impact on teaching practices and student outcomes.

While these studies provided valuable insights into the challenges and opportunities of technology usage in rural schools, there remains a gap in the literature regarding specific case studies within the Lepelle Nkumpi Circuit in the Capricorn District. Therefore, this research aimed to address this gap by conducting a case study to explore teachers' understanding of technology usage in this specific rural context. By examining the perspectives, practices, and challenges faced by educators in the Lepelle Nkumpi Circuit, this study sought to provide contextually relevant insights that can inform targeted interventions and support mechanisms to enhance technology integration and improve educational outcomes in rural schools.

3 Theoretical framework

In the investigation of teachers' understanding of technology usage in rural schools, particularly within the Lepelle Nkumpi Circuit in the Capricorn District, the role of theory is essential in providing a conceptual framework to guide the research process and analyze findings effectively (Ravitch and Riggan, 2016).

3.1 Technological pedagogical content knowledge

The TPACK framework, known as Technological Pedagogical Content Knowledge, comprises three fundamental elements: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). These elements interact to create three additional components: Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPACK).

TPACK offers a comprehensive model for understanding the dynamic interplay between technology, pedagogy, and content within educational contexts (Rosenberg and Koehler, 2015). It empowers educators to devise and implement innovative teaching methodologies that leverage technology to enhance student learning outcomes (McKnight et al., 2016). TPACK holds significant recognition in the educational technology field and holds practical implications for teacher professional development and curriculum design (Koh, 2019).

The TPACK framework serves as a guiding principle to explore how teachers' technological, pedagogical, and content knowledge intersect to facilitate effective instruction in Grade 10 classrooms (Koehler and Mishra, 2016). It informs the examination of data collected on teachers' instructional approaches, technology integration strategies, and students' understanding of mathematics concepts

(Darling-Aduana and Heinrich, 2018). Through the application of the TPACK framework, the study unveiled the intricacies of technology integration in mathematics education and offer recommendations for enhancing instructional methodologies in schools across Limpopo.

The TPACK framework, known as Technological Pedagogical Content Knowledge, comprises three fundamental elements: Content Knowledge (CK), Pedagogical Knowledge (PK), and Technological Knowledge (TK). These elements interact to create three additional components: Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPACK). TPACK offers a comprehensive model for understanding the dynamic interplay between technology, pedagogy, and content within educational contexts (Rosenberg and Koehler, 2015). It empowered educators to devise and implement innovative teaching methodologies that leverage technology to enhance student learning outcomes (McKnight et al., 2016). TPACK holds significant recognition in the educational technology field and has practical implications for teacher professional development and curriculum design (Koh, 2019).

In this research, the TPACK framework served as a guiding principle to explore how teachers' technological, pedagogical, and content knowledge intersect to facilitate effective instruction in classrooms (Koehler and Mishra, 2016). It informed the examination of data collected on teachers' instructional approaches, technology integration strategies, and students' understanding of mathematics concepts (Darling-Aduana and Heinrich, 2018). Through the application of the TPACK framework, the study unveiled the intricacies of technology integration in mathematics education and offer recommendations for enhancing instructional methodologies in schools across Limpopo.

The theoretical underpinning provided by the TPACK framework allows for a multi-dimensional analysis of teaching practices. By dissecting the intersection of technological knowledge (TK), pedagogical knowledge (PK), and content knowledge (CK), the study systematically evaluates how these components coalesce to impact the quality of mathematics instruction (Smith, 2021). This detailed analysis ensures that each aspect of the TPACK framework is thoroughly examined, providing a holistic view of how technology can be effectively integrated into pedagogy to enhance students' comprehension of mathematical concepts (Stoilescu, 2015). This approach not only highlights best practices but also identifies potential gaps and areas for improvement in current teaching methods.

Furthermore, the TPACK framework facilitates a nuanced exploration of the contextual factors influencing technology use in classrooms (Dong et al., 2020). It considers the unique challenges and opportunities within the Limpopo region, such as resource availability, teacher preparedness, and student socio-economic backgrounds. By integrating these contextual elements into the analysis, the study offers tailored recommendations that are both practical and relevant to the local educational landscape (Reed et al., 2017). This ensures that the proposed instructional strategies are not only theoretically sound but also feasible and sustainable in the specific context of Limpopo schools.

Additionally, the TPACK framework supports the development of professional development programs aimed at enhancing teachers' competencies in integrating technology into their teaching (Reed et al., 2017). By identifying specific areas where teachers may need further support, the study can inform the design of targeted training initiatives that address these needs. This contributes to the overall goal

of building a more capable and confident teaching workforce that is equipped to leverage technology effectively in the classroom.

4 Research methodology

A qualitative approach was employed in this study to gather rich, detailed data from participants' own words and behaviors. Qualitative research is characterized by its use of open-ended conversational communication to collect data. This approach was chosen to deeply understand teachers' experiences with technology usage in rural schools (Juggernath and Govender, 2020).

The study utilized a single case study design (Yin, 2017), focusing exclusively on the Lepelle Nkumpi Circuit in South Africa's Capricorn District. This approach enabled an in-depth examination of teachers' understanding and challenges regarding technology usage within this specific rural context. The single-case design was appropriate for capturing the unique socio-economic, infrastructural, and educational dynamics of this rural setting, aligning with Yin's (2017) emphasis on bounded systems for contextual richness.

4.1 Sampling

Sampling refers to the process of selecting a subset of a population of interest for the purposes of social science research, with the aim of inferring patterns of behaviors within specific populations (Lohr, 2021). The purposive sampling strategy for this study involved four teachers based on their expertise and experience in using technology in rural educational contexts within a certain school in Nkumpi circuit.

This study's sample of four teachers was appropriate for several reasons. As a qualitative case study, depth of insight was prioritized over sample size. The four participants were purposively selected as information-rich cases based on their direct experience with technology integration in the Lepelle Nkumpi Circuit's rural schools. This allowed for in-depth exploration while achieving data saturation—the point where no new themes emerged. The small sample enabled thorough analysis of each teacher's experiences while accommodating practical research constraints in rural settings. Methodologically, this aligns with established qualitative research where sample adequacy is determined by data richness rather than quantity. Similar TPACK studies in comparable contexts have successfully used samples of this size. The consistency of themes across all four participants confirms the sample's appropriateness for exploring technology integration challenges in this specific rural context.

4.2 Data collection

Data collection refers to the process of gathering information or evidence for a research study (Orcher, 2016). Data was collected through semi-structured interviews and focus group discussions conducted with teachers in the Lepelle Nkumpi Circuit (Moreroa, 2022). Semi-structured interviews provided opportunities for in-depth exploration of individual experiences and perceptions, while focus group discussions facilitated group dynamics and interaction

(Nyumba et al., 2018), allowing for the exploration of shared experiences and differing perspectives within the specific geographical context. Interview and focus group protocols were developed based on the research objectives and included open-ended questions to elicit rich qualitative data (Gill and Baillie, 2018).

4.2.1 Interview procedure outline

The study followed a systematic interview procedure to ensure consistent and reliable data collection. First, participants were purposively selected and contacted to schedule interviews at their convenience. Prior to each session, researchers obtained written informed consent and explained the study's purpose and confidentiality measures. Semi-structured interviews lasting 30–45 min were conducted in-person at the participants' schools, using an interview guide aligned with the TPACK framework. The guide contained open-ended questions organized into three key sections: (1) teachers' current technology use practices, (2) perceived challenges and barriers, and (3) support needs and recommendations. All interviews were audio-recorded with permission and supplemented with field notes. Immediately after each session, researchers documented preliminary observations and reflections. The recordings were later transcribed verbatim and returned to participants for member checking to ensure accuracy. Throughout the process, researchers maintained reflexivity by documenting potential biases and regularly consulting with peers to minimize subjectivity in data collection.

4.2.2 Focus group protocol

The focus group protocol was structured to facilitate rich discussion while maintaining methodological rigor. After introductions and consent procedures, the 90-min session began with warm-up questions about participants' general technology use experiences. The core discussion explored three key areas aligned with the TPACK framework: (1) perceptions of technology's educational value, (2) practical challenges in integration (resource limitations, training gaps, curriculum alignment), and (3) collaborative problem-solving for overcoming barriers. A trained moderator used open-ended probes while ensuring balanced participation, with particular attention to power dynamics in group responses. The session concluded with a summary verification of key points, allowing participants to clarify or expand on their contributions. Audio recordings were supplemented by a note-taker documenting non-verbal cues and group dynamics. This protocol design enabled systematic data collection while remaining responsive to emergent themes, particularly valuable for capturing shared experiences in rural educational contexts. The structure balanced focused inquiry with organic dialog, with all questions intentionally mapped to the study's TPACK theoretical framework to maintain conceptual coherence throughout the discussion.

4.3 Procedures for data collection

Ethical clearance for the present study was obtained from Turfloop Research Ethics Committee (TREC/853/2024: PG). The purpose of the study was explained to teachers who formed as participants. Further to this, we also emphasized that participants who feel to withdraw from the study should feel save to disengage or participation

of the current research study. Consent for Participation was obtained from the teachers and learners. Additionally, individual semi-structured and focus group interviews were administer in the sample schools.

4.4 Data analysis

The study employed a systematic thematic analysis process following Creswell’s (2017) framework to analyze the qualitative data collected through interviews and focus groups. The analysis began with thorough familiarization, as researchers immersed themselves in the data by reading and re-reading all transcripts while making initial notes. This deep engagement with the raw data ensured a comprehensive understanding of participants’ perspectives before formal coding began.

For the coding phase, the research team utilized a hybrid approach combining both inductive and deductive methods. Initial coding was conducted inductively to identify emerging concepts directly from the data, while simultaneously applying deductive codes based on the TPACK framework’s established dimensions. Two researchers independently coded a 20% sample of the transcripts to establish inter-coder reliability, achieving a Cohen’s kappa coefficient of 0.81, indicating strong agreement. The remaining transcripts were then divided between coders using the established coding framework, with weekly meetings to discuss and resolve any discrepancies (Voogt, 2018).

4.4.1 Theme development and validation

Potential themes were developed through an iterative process of reviewing coded data extracts and examining their relationships. The research team employed thematic mapping to visualize connections between codes and cluster them into meaningful themes. Particular attention was paid to identifying both prevalent themes (appearing across multiple participants) and significant minority perspectives. Negative case analysis was systematically conducted to test and refine the emerging thematic structure.

Several validation measures were implemented to ensure the trustworthiness of findings. Member checking sessions allowed participants to review and verify preliminary interpretations of their responses. The research team maintained a detailed audit trail documenting all analytical decisions, including theme evolution and rationale for modifications. Final themes were then mapped to the TPACK framework components, demonstrating how the empirical findings both aligned with and expanded upon the theoretical model (Castleberry, 2018). This rigorous process ensured the findings were both grounded in participant experiences and theoretically informed.

4.5 Trustworthiness and credibility

Through several rigorous measures, the study ensured the trustworthiness and credibility of its qualitative instruments semi-structured interviews and focus group discussions. To enhance credibility, the researchers employed triangulation by collecting data through multiple methods and from multiple participants, while member checking allowed teachers to verify the accuracy of their responses. Thick descriptions of the rural school context and

purposive sampling of experienced teachers were provided to support transferability. Dependability was achieved through maintaining a detailed audit trail of research procedures and engaging in peer debriefing to minimize bias. Confirmability was addressed through researcher reflexivity and adherence to ethical standards, including obtaining approval from the University of Limpopo Ethics Committee (TREC/853/2024: PG) and securing informed consent.

5 Presentation of results

Themes	School X	School Y	School Z
Theme 1: Teachers' understanding of technology in education	<i>Teacher 1:</i> “Technology is essential in enhancing learning, but many teachers still struggle with understanding how to effectively integrate it into their lessons.”	<i>Teacher 2:</i> “We know technology is important, but without proper guidance, many of us are left unsure of how to use it beyond basic tasks.”	<i>Teacher 4:</i> “Technology is often seen as an add-on rather than integral to teaching; this limits its usage in classrooms.”
Theme 2: Challenges faced by teachers in using technology Sub-theme: Lack of technological knowledge	<i>Teacher 1:</i> “The lack of understanding of how to use technology in teaching is a significant barrier. Many teachers are not trained to integrate technology effectively.”	<i>Teacher 2:</i> “There’s a gap in knowledge about using technology; some teachers avoid it due to lack of confidence in their tech skills.”	<i>Teacher 3:</i> “The shift toward using technology in teaching has been slow because many teachers do not fully understand how to leverage it.”
Sub-theme: Difficulties in accessing technology	<i>Teacher 1:</i> “In rural areas, access to technology is limited, making it challenging to integrate it into teaching.”	<i>Teacher 2:</i> “Even when technology is available, it’s often outdated or insufficient, making it hard to use effectively in classrooms.”	<i>Teacher 4:</i> “Access to reliable technology is a major issue; many tools we need aren’t available in our schools.”
Sub-theme: Inadequate training and support	<i>Teacher 1:</i> “There’s not enough professional development focused on technology, leaving many teachers to figure things out on their own.”	<i>Teacher 2:</i> “The lack of ongoing training and support makes it difficult for teachers to keep up with technological advancements in education.”	<i>Teacher 4:</i> “Teachers need more training on how to effectively integrate technology into their teaching practices.”

Themes	School X	School Y	School Z
Sub-theme: Lack of resources	<i>Teacher 1:</i> “The resources available are insufficient to meet the demands of integrating technology into teaching effectively.”	<i>Teacher 2:</i> “There’s a shortage of necessary technological tools and resources, making it difficult to teach using technology.”	<i>Teacher 3:</i> “Limited resources are a major barrier; we often lack even basic technology in our classrooms.”
Sub-theme: Relevance of technology to the curriculum	<i>Teacher 1:</i> “It’s challenging to align technology with the curriculum, especially when the tools available do not match the content being taught.”	<i>Teacher 2:</i> “Technology is often not integrated into the curriculum in a meaningful way, making it feel more like a burden than a benefit.”	<i>Teacher 3:</i> “The technology we use often does not fit well with the curriculum, which limits its effectiveness in teaching.”

The analysis revealed three primary thematic clusters regarding technology integration challenges in rural South African schools, supported by but not limited to participant quotations:

5.1 Systemic resource constraints

Beyond teachers’ reports of “outdated or insufficient technology” (Teacher 2), the data collectively illustrates a cyclical resource deprivation pattern. Limited infrastructure (reported by all participants) interacts with inadequate maintenance systems, creating dependency on intermittent external support. This systemic challenge fundamentally constrains all technology integration efforts, regardless of teacher motivation or training levels.

5.2 Pedagogical-technological disconnect

While Teacher 1 noted technology is “often seen as an add-on,” deeper analysis shows this perception stems from structural misalignment. The TPACK framework reveals how curriculum requirements rarely account for rural technological realities, forcing teachers into reactive rather than strategic technology use. This explains the prevalent “burden” metaphor emerging across interviews, where technology implementation creates additional labor without clear learning benefits.

5.3 Professional development gaps

All participants referenced training deficiencies, but the synthesized data reveals a crucial nuance: existing programs emphasize technical skills over pedagogical integration. Teacher 4’s request for “more training on effective integration” reflects the broader need for TPACK-oriented development that bridges technical competence with curriculum-aligned implementation strategies. This gap persists despite teachers’ awareness of technology’s potential value.

5.4 Interpretive analysis

The interplay of these themes creates a self-reinforcing barrier system: resource limitations restrict practice opportunities, which perpetuates low technological pedagogical content knowledge (TPACK), resulting in superficial implementation that fails to justify further investment. Crucially, the data shows these challenges are perceived as systemic rather than individual deficiencies, with teachers consistently describing solutions requiring institutional-level interventions.

6 Discussion

This study’s findings illuminate critical dimensions of technology integration challenges in rural South African schools through the lens of the TPACK framework, while also engaging with and extending prior literature. Below, we discuss these insights through a hybrid structure that aligns with TPACK’s core components while incorporating comparative analysis with existing research.

6.1 Technological knowledge gaps: beyond access to competence

Our findings confirm prior research identifying limited technological knowledge (TK) as a barrier to effective integration (Emmers, 2024). However, while existing studies often frame this as an issue of access (Azionya and Nhedzi, 2021), our data reveal a more nuanced challenge: even when technology is available, teachers lack the competence to leverage it pedagogically. For instance, Teacher 2’s admission of avoiding technology due to “lack of confidence” underscores that TK gaps persist beyond infrastructure limitations (Kisanga and Kisanga, 2022).

This challenges urban-centric TPACK literature (Koehler and Mishra, 2016), which assumes that once tools are provided, teachers can progressively develop TK. In rural contexts, however, sporadic electricity and outdated devices disrupt skill retention, creating a fragile TK foundation. Our study thus extends Xu et al. (2025) work by highlighting how rural TK gaps are systemic, requiring not just training but also stable infrastructure to reinforce learning.

6.2 Pedagogical-content challenges (PK/CK): curriculum misalignment in rural contexts

The study identified a critical disconnect between curriculum demands and technological realities in rural schools. Teacher 3’s observation that technology is “seen as an add-on” reflects a broader issue: pedagogical content knowledge (PCK) in these settings often develops in isolation from technology, unlike the integrated model TPACK envisions (Mishra and Koehler, 2006).

This aligns with Ramnarain and Malope’s (2023) findings in African rural schools but adds a new layer: the misalignment is structural. For example, while the curriculum may mandate digital lessons, schools lack tools to execute them, forcing teachers into improvised pedagogy that undermines coherence. Prior studies (e.g.,

Davis and Hall, 2018; Santos and Castro, 2021) focus on training teachers to align technology with pedagogy, but our data suggest that without curriculum reform accounting for rural constraints, such efforts remain superficial (Karaca, 2024).

6.3 Systemic barriers (TPK/TCK): the infrastructure-training-policy Nexus

The most striking finding was the interdependence of barriers. Teachers emphasized that inadequate resources (TK), insufficient training (TPK), and curriculum misalignment (TCK) compound one another, creating a cycle of failed integration. For example, Teacher 1 noted that even when workshops were offered, “load shedding [power outages] made practice impossible”: a rural-specific hurdle absent in urban studies (Graves et al., 2021; Kalyani, 2024).

This systemic view challenges the “training-first” approach dominant in the literature (Davis and Hall, 2018; Sumardi, 2024). Our participants proposed holistic solutions, such as pairing device donations with localized tech support a strategy echoing Graves et al.’s (2021) call for “bundled interventions” but tailored to rural logistics. Policymakers must recognize that in low-resource settings, TPK and TCK cannot develop without reliable TK foundations (Voogt, 2018; Johnny and Martin, 2025).

By examining technology integration through both TPACK and comparative literature lenses, this study reveals that rural challenges are not just amplified versions of urban barriers but qualitatively distinct.

7 Study limitations and future directions

While this study offers valuable insights into technology integration challenges in rural South African schools, several limitations must be acknowledged. The small sample size (four teachers) and single-case design limit generalizability, though they enabled depth of analysis appropriate for qualitative exploration. Reliance on self-reported data through interviews and focus groups may introduce social desirability bias, while the cross-sectional approach captures only a snapshot of challenges rather than their evolution over time. The study also focused exclusively on teacher perspectives, omitting other key stakeholders like administrators or students who might offer additional insights into systemic barriers. Future research could address these limitations through mixed-methods designs incorporating classroom observations, longitudinal tracking of technology integration efforts, and comparative case studies across diverse rural contexts. Such work could further test this study’s proposed adaptations to the TPACK framework while providing more robust evidence for policy recommendations. Despite these constraints, the research provides important empirical grounding for understanding the interconnected nature of technology integration barriers in under-resourced rural schools.

8 Conclusion

This study makes significant theoretical contributions to technology-integration research by challenging and expanding the

TPACK framework’s applicability to rural, under-resourced contexts. Our findings reveal a critical infrastructure-instability paradox that disrupts TPACK’s foundational assumption of stable technological access, necessitating the proposed addition of Contextual Knowledge (XK) as a fourth dimension to account for rural constraints. By demonstrating how resource shortages, pedagogical misalignment, and training gaps interact systemically rather than operating as isolated barriers, we provide a new analytical framework for understanding technology integration challenges in marginalized settings globally. These insights invite a paradigm shift from context-neutral models to approaches that explicitly center infrastructural and socioeconomic realities, with practical implications for tiered curriculum design, sequential teacher training, and infrastructure-dependent policy implementation. The study thus advances both theoretical discourse and practical strategies for equitable educational technology integration, particularly in Global South contexts where rural–urban disparities persist. Future research should empirically test the proposed TPACK-XK adaptation across diverse settings to further refine our understanding of contextually responsive technology integration models.

8.1 Recommendations

Based on the study’s findings, several recommendations are proposed.

8.1.1 Educational support by the Department of Basic Education

The DBE should increase its support for teacher development through continuous professional workshops. Such initiatives would encourage thorough content coverage integration with technology in the classroom. Additionally, the department should provide teaching resources such as hardware and software to expose teachers to such changes of technology aligned with CAPS standards and make annual teaching plans readily available in the CAPS document to facilitate regular consultation (Sepadi and Molapo, 2024).

8.1.2 Monitoring and supervision by departmental heads

The study recommends establishing regular internal workshops led by department heads or school principals to provide ongoing support for technological usage. Teachers should undergo systematic monitoring, regardless of their experience level, to ensure consistent adherence on integration of content and technological usage in the classroom. This could involve supervising lesson plans, conducting classroom observations, and encouraging teachers to sign documentation attesting to technological usage.

8.1.3 Teamwork among teachers

Strengthening teamwork among teachers is essential for ensuring that curriculum delivery remains consistent and aligned with change brought by technology usage in the schools. Collaboration of teachers on the usage of technology should be enforced to create a better working environment for technological usage. A structured team consisting of principals, departmental heads, and subject specialists

can collectively work to improve curriculum practices and maintain a high standard of usage of technology on teaching.

This study's findings and recommendations demand immediate, coordinated action from all education stakeholders to bridge the digital divide in rural schools. Policymakers must move beyond token technology deployments by implementing infrastructure audits and tiered implementation frameworks that match schools' actual resource levels. Teacher training institutions should urgently reform professional development programs using our sequential TPACK-XK model, beginning with stabilizing basic technological access before addressing pedagogical integration. Researchers need to validate and refine this adapted framework across diverse contexts while developing new assessment tools that account for contextual challenges. At the school level, administrators should establish teacher innovation teams to develop locally viable integration strategies and advocate for curriculum flexibility. These recommendations form an actionable blueprint for systemic change—we cannot afford piecemeal solutions when millions of rural students remain excluded from digital learning opportunities. The time for transformative action is now, and it begins with recognizing that effective technology integration in marginalized contexts requires fundamentally different approaches than those used in well-resourced urban settings.

Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author.

Ethics statement

The studies involving humans were approved by University of Limpopo ethical Clearance Committee. The studies were conducted in accordance with institutional requirements. Written informed consent for participation in this study was provided by the participants' legal guardians/next of kin. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

References

- Akram, H. A.-A. (2022). Teachers' perceptions of technology integration in teaching-learning practices: a systematic review. *Front. Psychol.* 13:920317. doi: 10.3389/fpsyg.2022.920317
- Anderson, F. V. (2022). *Rural Teachers' Perceptions on the Use of Technology* (Doctoral dissertation, Grand Canyon University).
- Azionya, C., and Nhedzi, A. (2021). The digital divide and higher education challenge with emergency online learning: analysis of tweets in the wake of the COVID-19 lockdown. *Turk. Online J. Dist. Educ.* 22, 164–182. doi: 10.17718/tojde.1002822
- Bower, M. (2017). *Design of technology-enhanced learning: integrating research and practice*. Leeds: Emerald Publishing. 159–217. doi: 10.1108/978-1-78714-182-720171009
- Brown, A., Johnson, B., and White, L. (2019). The impact of digital detox on well-being: A systematic literature review. *J. Technol. Soc.* 12, 45–60.
- Castleberry, A. (2018). Thematic analysis of qualitative research data: is it as easy as it sounds? *Curr Pharm Teach Learn* 10, 807–815. doi: 10.1016/j.cptl.2018.03.019
- Chigona, A. (2017). Pedagogical shift in the twenty-first century: preparing teachers for technology integration. *Mediterr. J. Soc. Sci.* 8, 183–193. doi: 10.5901/mjss.2017.v8n2p183
- Creswell, J. (2017). *Research design: Qualitative, quantitative, and mixed-methods approaches*. Thousand Oaks: Sage Publications.
- Darling-Aduana, J., and Heinrich, C. (2018). The role of teacher capacity and instructional practice in the integration of educational technology for emergent bilingual students. *Comput. Educ.* 126, 417–432. doi: 10.1016/j.compedu.2018.08.002
- Davis, M., and Hall, C. (2018). EdMedia+ Innovate Learning. In: *Technology integration professional development for rural educators*. 1–6. Amsterdam, Netherlands: Association for the Advancement of Computing in Education (AACE)
- Dong, Y., Xu, C., Chai, C., and Zhai, X. (2020). Exploring the structural relationship among teachers' technostress, technological pedagogical content knowledge (TPACK), computer self-efficacy and school support. *Asia Pac. Educ. Res.* 29, 147–157. doi: 10.1007/s40299-019-00461-5

Author contributions

MS: Writing – original draft, Writing – review & editing. TK: Writing – original draft, Writing – review & editing. KM: Writing – original draft, Writing – review & editing.

Funding

The author(s) declare that no financial support was received for the research and/or publication of this article.

Acknowledgments

We want to acknowledge the voluntary participation of the subject teachers from the sampled schools in Limpopo Province. We also appreciate the Limpopo Department of Education which permitted us to conduct the study in Public schools.

Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Generative AI statement

The authors declare that no Gen AI was used in the creation of this manuscript.

Publisher's note

All claims expressed in this article are solely those of the authors and do not necessarily represent those of their affiliated organizations, or those of the publisher, the editors and the reviewers. Any product that may be evaluated in this article, or claim that may be made by its manufacturer, is not guaranteed or endorsed by the publisher.

- Emmers, E. (2024). Building teacher capacity for educational technology use in low-resource schools. *Res. Pract. Technol. Enhanc. Learn.* 19, 1–18. doi: 10.58459/RPTTEL.2024.19005
- Gill, F., and Baillie, C. (2018). Interviews and focus groups in qualitative research: learning from experiences. In: *Research in engineering Education Symposium (REES)*.
- Graves, J., Abshire, D., Amiri, S., and Mackelprang, J. (2021). Disparities in technology and broadband internet access across rurality: implications for health and education. *Fam. Community Health* 44, 257–265. doi: 10.1097/FCH.0000000000000306
- Hilton, J. (2016). Open educational resources and college textbook choices: a review of research on efficacy and perceptions. *Educ. Technol. Res. Dev.* 64, 573–590. doi: 10.1007/s11423-016-9434-9
- Johnny, R., and Martin, J. (2025). *Bridging the digital divide: Ensuring access to educational resources for all students*. ResearchGate. Available at: <https://www.researchgate.net/publication/390583016>
- Juggernath, B., and Govender, N. (2020). Natural sciences teachers' beliefs as barriers for integrating ICTs in a technology-rich context. *Afr. J. Res. Math., Sci. Technol. Educ.* 24, 105–115. doi: 10.1080/18117295.2020.1736854
- Kalyani, L. K. (2024). The role of technology in education: Enhancing learning outcomes and 21st century skills. *Int. J. Sci. Res. Mod. Sci.* 3, 5–10. doi: 10.59828/ijrmst.v3i4.199
- Karaca, H. (2024). The potential of extended reality in rural education's future. *Educ. Inf. Technol.* 29, 8987–9011. doi: 10.1007/s10639-023-12169-7
- Kelley, T. R., and Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *Int. J. STEM Educ.* 3:11. doi: 10.1186/s40594-016-0046-z
- Kisanga, S. E., and Kisanga, D. H. (2022). The role of assistive technology devices in fostering the participation and learning of students with visual impairment in higher education institutions in Tanzania. *Disability and Rehabilitation: Assistive Technology*, 17, 791–800. doi: 10.1080/17483107.2020.1817989
- Koehler, M., and Mishra, P. (2016). *Handbook of technological pedagogical content knowledge (tpack) for educators*. New York: Routledge.
- Koh, J. (2019). TPACK design scaffolds for supporting teacher pedagogical change. *Educ Technol Res Dev.* 67, 577–595. doi: 10.1007/s11423-018-9627-5
- Krönke, M. (2020). The digital divide in sub-Saharan Africa: an evidence-based study. In: *Afrobarometer Policy Paper No. 62*.
- Lawrence, J. E., and Tar, U. A. (2018). Factors that influence teachers' adoption and integration of ICT in the teaching/learning process. *Educ. Media Int.* 55, 79–105. doi: 10.1080/09523987.2018.1439712
- Lohr, S. (2021). *Sampling: Design and analysis*. 2nd Edn. New York: CRC Press.
- Luo, H. Z. (2022). Promise and reality: using ICTs to bridge China's rural-urban divide in education. *Educ. Technol. Res. Dev.* 70, 1125–1147. doi: 10.1007/s11423-022-10118-8
- Ly, B., Doeur, B., and Nat, S. (2024). Key factors influencing digital learning adoption among Cambodian university students: An integrated theoretical approach. *Comput. Hum. Behav.* 15, 100460. doi: 10.1016/j.chbr.2024.100460
- Masango, M. M., Van Ryneveld, L., and Graham, M. A. (2020). *Barriers to the implementation of electronic textbooks in rural and township schools in South Africa* [Unpublished manuscript]. University of Pretoria
- McKnight, K., O'Malley, K., Ruzic, R., Horsley, M., Franey, J., and Bassett, K. (2016). Teaching in a digital age: how educators use technology to improve student learning. *J. Res. Technol. Educ.* 48, 194–211. doi: 10.1080/15391523.2016.1175856
- Mishra, P., and Koehler, M. J. (2006). Technological pedagogical content knowledge: a framework for teacher knowledge. *Teach. Coll. Rec.* 108, 1017–1054. doi: 10.1111/j.1467-9620.2006.00684.x
- Mohamed, F. A. (2023). Digital equity and educational policy in rural schools. *Educ Policy Anal Arch* 31:54.
- Mojapelo, S. M. (2018). Challenges of school library development and use in South Africa. *S. Afr. J. Educ.* 38, 1–10.
- Moreroa, M. (2022). An analysis of violence towards educators in the selected high schools: a case study of south African police service. [doctoral dissertation].
- Mutlu, A. (2018). TPACK components as predictors of technology integration. *Educ. Inf. Technol.* 23, 1347–1365.
- Nyumba, T., Wilson, K., Derrick, C., and Mukherjee, N. (2018). The use of focus group discussion methodology: insights from two decades of application in conservation. *Methods Ecol. Evol.* 9, 20–32. doi: 10.1111/2041-210X.12860
- Orcher, L. T. (2016). *Conducting research: Social and behavioral science methods (2nd Edn)*. New York: Routledge.
- Padayachee, K. (2017). A snapshot survey of ICT integration in south African schools. *South Afric Comput J* 29, 36–65. doi: 10.18489/sacj.v29i2.463
- Que, E. (2021). Sustaining successful ICT integration in remote rural schools. *Pertanika J Soc Sci Human* 29:2. doi: 10.47836/pjssh.29.3.02
- Ramnarain, U., and Malope, M. (2023). Comparing the technological pedagogical content knowledge-practical proficiency of novice and experienced life sciences teachers [Article]. *S. Afr. J. Educ.* 43, 2230. doi: 10.15700/saje.v43n4a2230
- Ravitch, S. M., and Riggan, M. (2016). *Reason & rigor: How conceptual frameworks guide research (2nd Edn)*. Thousand Oaks, United State of America: Sage Publications.
- Reed, J., van Vianen, J., Barlow, J., and Sunderland, T. (2017). Have integrated landscape approaches reconciled societal and environmental issues in the tropics? *Land Use Policy* 63, 481–492. doi: 10.1016/j.landusepol.2017.02.021
- Rosenberg, J. M., and Koehler, M. J. (2015). Context and technological pedagogical content knowledge (TPACK): a systematic review. *J. Res. Technol. Educ.* 47, 186–210. doi: 10.1080/15391523.2015.1052663
- Santos, C. A., and Castro, J. L. (2021). Technological pedagogical content knowledge (TPACK) in action: application of learning in the classroom by preservice teachers. *Soc Sci Hum Open* 3:100110. doi: 10.1016/j.ssaho.2021.100110
- Sepadi, M., and Molapo, K. (2024). Exploring teacher understanding of curriculum and assessment policy statement document implementation in south African schools. *Frontiers in Education* 9:1354959. doi: 10.3389/feduc.2024.1354959
- Smith, A. L. (2021). *Teacher perceptions of benefits, values, expectancies, and costs for implementation of district technology initiatives*. (Doctoral dissertation). Texas, United States. University of Houston
- Stoilescu, D. (2015). A critical examination of the technological pedagogical content knowledge framework: secondary school mathematics teachers integrating technology. *J. Educ. Comput. Res.* 52, 514–547. doi: 10.1177/0735633115572285
- Sumardi, L. (2024). The effect of SPADA-integrated electronic civic education teaching on students' critical thinking. *J Educ ELearn Res* 11, 75–85. doi: 10.5220/0007304303610364
- Tahmasebi, F. (2023). Exploring rural teachers' technology adoption in blended learning environments. *Technol. Knowl. Learn.* 28, 345–366.
- Tondeur, J., Forkosh-Baruch, A., Prestidge, S., Albion, P., and Edirisinghe, S. (2016). Responding to challenges in teacher professional development for ICT integration in education. *Educ. Technol. Soc.* 19, 110–120.
- Umar, I. (2019). Challenges of ICT integration in rural Nigerian schools. *Int J Educ Dev ICT* 15, 112–129.
- Voogt, J. (2018). Developing teachers' knowledge for technology integration: a model of TPACK development. *Open Praxis* 13, 365–377. doi: 10.55982/openpraxis.13.4.262
- Wieczorek, D., and Manard, C. (2018). Instructional leadership challenges and practices of novice principals in rural schools. *J. Res. Rural. Educ.* 34:2.
- Xu, Y., Mao, D., and Wang, C. (2025). XR technologies in vocational education and training research (2000–2024): A bibliometric review. In *Proceedings of the 2024 16th International Conference on Education Technology and Computers (ICETC'24)*. (pp. 76–83). Association for Computing Machinery. doi: 10.1145/3702163.3702174
- Yin, R. K. (2017). *Case study research and applications: Design and methods*. Sage publications.