Research Article

e-ISSN: 2710-2122, p-ISSN: 2710-2114
2025: Vol 7(s1), pp 1-16. https://doi.org/10.38140/ijer-2025.vol7.s1.15
Interdisciplinary Journal of Education Research

Navigating the Digital Divide in Open Distance and e-Learning: Perspectives from Urban and Rural Student Teachers

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EDITORIAL DATES
Received: 19 August 2024
Revised: 04 June 2025
Accepted: 13 October 2025
Published: 27 October 2025

DOI: 10.38140/ijer-2025.vol7.s1.15

Abstract: In an era of digital transformation, integrating technology into education is essential; yet disparities in access, literacy, and engagement persist between urban and rural student teachers. This study examines these differences within an Open Distance and e-Learning (ODeL) institution, focusing on student teachers during their teaching practice. Grounded in Digital Divide Theory and the Technological Pedagogical Content Knowledge (TPACK) framework, the study employs a qualitative multi-case approach to compare the digital experiences of urban and rural student teachers in South Africa. The study involved sixteen purposively selected fourth-year student teachers, comprising ten from rural schools and six from urban schools, who were completing their teaching practice within the College of Education. Findings reveal that rural student teachers face significant barriers, including unreliable internet, limited digital resources, and inadequate institutional support. At the same time, their urban counterparts benefit from structured digital training and greater access to technological tools. Additionally, gaps in digital literacy are evident, with rural student teachers relying on mobile-based tools and self-directed learning, whereas urban students engage with more advanced digital platforms. These disparities impact their ability to integrate technology effectively into classroom instruction. The study concludes that addressing the digital divide in teacher education requires more than just device access. Targeted interventions, such as digital literacy training, mentorship programmes, and improved infrastructure, are critical for equitable technology integration.

Keywords: Digital divide, digital literacy, open distance and e-learning, technology integration, teacher training, teaching practice.

1. Introduction

Integrating digital tools into education has become essential for effective teaching and learning in an era of rapid technological advancement. Yet, as Qaribilla et al. (2024) argue, persistent digital divides hinder equitable access to education. These divides extend beyond devices to include disparities in digital literacy, engagement, and the enabling conditions shaped by geography, socio-economic status, and institutional support, as highlighted in recent studies by Brugnera et al. (2024) and Ying et al. (2024). The result is that rural and urban student teachers often face starkly different opportunities and challenges regarding educational technology.

In South Africa, digital inequality is deeply rooted in the country's historical and structural inequities. Makalima et al. (2023) demonstrate how rural communities remain systematically disadvantaged in infrastructure and resource provision, a reality shaped by colonial and apartheid-era spatial planning. These inequalities are further compounded by uneven institutional support, which Ngoveni (2025a) shows continues to undermine efforts to bridge digital divides in higher education. The persistence of these inequities means that access to electricity, connectivity, and digital resources remains precarious in rural schools, whereas urban schools benefit from more

How to cite this article:
Mphuthi, G. T., Ngoveni, M. A., & Mphahlele, R. S. (2025). Navigating the digital divide in open distance and e-learning: perspectives from urban and rural student teachers. *Interdisciplinary Journal of Education Research, 7*(s1), a15. https://doi.org/10.38140/ijer-2025.vol7.s1.15

consistent investment and technological provision. Mphahlele et al. (2024) illustrate how these disparities directly affect teacher education, showing that student teachers in rural schools frequently struggle with unreliable electricity, poor internet connectivity, and limited institutional backing, while their urban counterparts have access to structured digital training and advanced teaching tools. Such findings reinforce the broader argument that digital exclusion in South Africa is not merely a technical issue but rather a continuation of structural inequality: the same communities historically denied quality education and economic opportunity are now being left behind in the digital era.

Teaching practice is vital to teacher training, providing student teachers with experience in classroom settings. It bridges theoretical knowledge and practical application, helping student teachers develop instructional competencies, classroom management skills, and pedagogical adaptability (Ndebele & Legg-Jack, 2022; Ngcapu et al., 2024). Mphahlele et al. (2024) posit that effective supervision is essential to ensure that student teachers receive constructive feedback, refine their teaching strategies, and address challenges encountered in the classroom.

This study specifically investigates how digital access, digital literacy, and technology use vary between rural and urban student teachers during teaching practice in an Open Distance and e-Learning (ODeL) context. By focusing on these dimensions, it seeks to illuminate how structural inequalities influence pre-service teachers' readiness for technology integration and identify targeted interventions that could promote equitable digital preparation. In an Open Distance e-Learning (ODeL) institution, student teacher supervision is conducted through a dual-structure system involving internal and external supervisors. Internal supervisors are lecturers within the College of Education, while external supervisors are academics contracted by the university (Mphahlele et al., 2024; Age & Machaba, 2024; Pule et al., 2025). These supervisors are expected to guide student teachers, assess their lesson delivery, and provide additional support.

The digital divide in education manifests in several dimensions. Urban teachers have better infrastructure, higher internet connectivity, and more robust training in digital literacy. Conversely, rural teachers encounter barriers, including limited access to devices and connectivity, inadequate professional development, and insufficient institutional support (Waqar et al., 2024). These challenges are mirrored globally, with studies highlighting the struggles of rural schools in Colombia, Pakistan, and South Africa in leveraging technology effectively (Baena-Navarro et al., 2024; Makalima et al., 2023).

Although prior studies in South Africa have examined digital access and ICT integration in schools, they have rarely compared the experiences of rural and urban pre-service teachers during teaching practice, particularly in an ODeL setting (Makalima et al., 2023; Mphahlele et al., 2024; Nkambule, 2023). Much of the existing work focuses on in-service teachers or general infrastructure, leaving a gap in understanding how pre-service teachers navigate and adapt to the digital conditions of their placement schools. This study addresses this gap by providing a comparative, context-sensitive account of teaching practice under varying digital resource conditions.

Moreover, the digital divide is exacerbated by varying levels of digital literacy, with urban teachers and students generally more proficient due to greater access to technology. In contrast, rural educators often lack the necessary resources and training (Wang & Zhang, 2024). Gutiérrez-Ángel et al. (2022), analysing PISA 2018 data, identify marked global disparities in digital skills and conclude that strengthening digital competence is essential for sustainable education and social development. This disparity impacts teaching practices and limits the creation of inclusive, technology-driven learning environments (Afzal et al., 2023). Hence, this article investigates disparities in technology use among urban and rural student teachers during their training. Grounded in Technological Pedagogical Content Knowledge (TPACK) and Digital Divide Theory, it explores how differences in access, literacy, and engagement affect their preparedness to integrate technology into teaching. The

study aims to inform educational policies that promote equitable digital access for all future educators. Therefore, the study was piloted via the following research questions:

- RQ1: What differences exist in digital access between rural and urban student teachers during teaching practice?
- RQ2: How do rural and urban student teachers differ in their digital literacy levels during teaching practice?
- RQ3: How do rural and urban student teachers use digital tools during teaching practice?
- RQ4: What targeted interventions can promote equitable technology integration in teaching practice for rural and urban student teachers?

2. Theoretical Framework

Understanding the challenges of digital integration in teacher education requires a dual-theoretical lens that captures both structural barriers and pedagogical competencies. This study employs the Digital Divide Theory and the Technological Pedagogical Content Knowledge (TPACK) framework to analyse disparities in access, digital literacy, and technology use among urban and rural student teachers. By combining these theories, a holistic view is achieved of the external factors affecting technology adoption and the internal knowledge structures influencing pedagogical implementation.

2.1 Digital divide theory

Van Dijk's framework explains digital inequality through three interdependent dimensions, namely material access, skills access, and usage access. It argues that these disparities are cumulative and mutually reinforcing (Van Dijk, 2005). Material access concerns the availability, reliability, and affordability of devices, connectivity, and power—conditions that are typically more stable in urban areas than in rural contexts, where intermittent bandwidth and electricity interruptions constrain participation (Age & Machaba, 2024; Mphahlele et al., 2024; Waqar et al., 2024). Skills access refers to operational and strategic digital literacies that develop through exposure, guided practice, and institutional support. Within teaching practice, mentoring functions as a mechanism for skills acquisition because experienced teachers model context-appropriate tool use and scaffold novices' classroom decision making (Angeli & Valanides, 2009; Ertmer & Ottenbreit-Leftwich, 2010; Harris & Hofer, 2011). Usage access concerns the extent and quality of technology use for valued educational purposes. Where access and skills are constrained, technology tends to be used sporadically or functionally, while stronger access and support widen the scope for regular and pedagogically purposeful use (Kormos & Wisdom, 2023; Nkambule, 2023).

2.2 Technological pedagogical content knowledge (TPACK)

The TPACK framework posits that effective technology integration occurs when technological knowledge is coherently combined with pedagogical and content knowledge, leading to context-appropriate instructional choices (Harris & Hofer, 2011; Mishra & Koehler, 2006). During teaching practice, structured professional learning and guided mentoring enable student teachers to select and adapt digital tools to mathematical ideas, task designs, and assessment strategies, thereby transforming generic tool familiarity into subject-specific pedagogy (Angeli & Valanides, 2009; Ertmer & Ottenbreit-Leftwich, 2010; Harris & Hofer, 2011). In contexts where training and infrastructural support are limited, as is often the case in rural placements, student teachers struggle to align technology with lesson objectives, resulting in more functional than transformative uses (Goh & Kale, 2015; Nkambule, 2023).

2.3 Integrative theoretical position

Taken together, the two lenses provide a structural and pedagogical account of the differences in teaching practice between rural and urban settings. The digital divide framework clarifies why

opportunities to develop skills and use tools vary across placements by specifying inequalities in material access and the conditions for skills acquisition. In contrast, TPACK elucidates how these unequal preconditions manifest in instructional design and enactment. In this study, constrained material access limits opportunities for guided practice, while limited skills restrict the scope and quality of usage. Additionally, restricted usage reduces the likelihood of pedagogically meaningful integration. Conversely, where access and mentoring are stronger, students are better positioned to realise TPACK-aligned practices. This integrated perspective offers a coherent pathway from structural conditions to classroom practice and aligns directly with the comparative research questions regarding access, literacy, and technology use in teaching practice.

3. Literature Review

The role of technology in teacher education is widely recognised; however, disparities in digital access, literacy, and engagement persist across different geographical contexts. This literature review examines the complexities of technology integration within teacher training, focusing on infrastructural challenges, the development of digital literacy, and the impact of national policies on mitigating digital inequalities.

3.1 Material access during teaching practice

Omodan (2022) shows that rural placements are characterised by unreliable connectivity, scarce devices, and school-level constraints—conditions that narrow what student teachers can realistically plan and enact. Mathematics-focused work in an open distance and e-learning setting echoes this pattern by linking uneven provision to difficulties in modelling effective practice during external supervision, as well as to variability in school-based support that affects lesson preparation and assessment (Mphahlele et al., 2024). Supervisory capacity is not neutral in this equation; where external supervisors themselves face access limitations in ODeL, the support student teachers receive can be dampened, whereas stronger digital inclusion enables more consistent guidance (Age & Machaba, 2024).

International evidence indicates that these patterns are not unique to South Africa. Large-sample research in China reports a pronounced urban–rural gap in teachers' digital environments and literacies, which translates into differences in ICT competence, reinforcing the argument that infrastructure and institutional provision shape classroom possibilities (Zhao et al., 2024). A comparative analysis of preparation for rural and remote schooling adds that university expectations can outpace placement realities in Australia, South Africa, and Mexico, sustaining misalignment between coursework and field conditions (Ledger et al., 2021). In a South African ODeL mathematics context, Ngoveni (2025b) demonstrated that the structured use of WhatsApp groups significantly improved student performance by enhancing peer support, modelling, and motivation, illustrating how low-bandwidth platforms can help overcome access challenges and promote sustained engagement. Together, these strands support a structural view of material access and justify a comparative rural–urban lens while underscoring the need for a teaching practice-specific account in mathematics within ODeL.

3.2 Skills access, mentoring and professional learning during teaching practice

Ngcapu et al. (2024) argue that aligning coursework with fieldwork and scaffolding expectations for ICT integration provides student teachers with clearer trajectories for growth in classroom-relevant skills such as resource selection, task design, and assessment. In many South African rural placements, however, mentoring is sparse and context-appropriate modelling is limited, which restricts the development of operational and strategic digital literacies in situ, as Omodan (2022) observes. The quality of mentoring during teaching practice consistently emerges as a determinant of pedagogical development, with modelling and feedback shaping how novices appropriate tools for instruction and meet professional requirements (Ndebele & Legg-Jack, 2022).

In mathematics-specific ODeL contexts, targeted feedback, reflective conferencing, and deliberate mentoring convert limited material opportunities into practicable skills for lesson preparation and enactment (Mphahlele et al., 2024). Where supervisors possess stronger digital inclusion, feedback loops and technology-mediated guidance are more feasible across dispersed placements, reinforcing the skills pathway implied in the digital divide model (Age & Machaba, 2024). International reviews converge on these mechanisms; sustained coaching, practice, and feedback matter more for teacher learning than hardware provision alone in low- and middle-income countries (Hennessy et al., 2022), while a review of reviews cautions that fragmented interventions yield limited effects and calls for coherent programmes that integrate coursework, teaching practice, and reflective cycles around technology integration (Schmid et al., 2024).

3.3 Usage during classroom enactment

Ramnarain et al. (2021) provide South African evidence that, under supportive conditions, pre-service teachers move beyond functional tool use toward integrated applications in planning and instruction, although proficiency varies across cohorts and settings. In many resource-constrained teaching practice schools, however, usage remains sporadic or demonstrative because time, infrastructure, and mentoring do not sustain iterative lesson design and reflection that enable technology to support conceptual understanding in mathematics. Mathematics-focused supervision studies identify practical strategies that enhance usage quality despite constraints, including structured feedback cycles, reflective conferencing, and peer observation, each linked to more coherent lesson planning and enactment (Pule et al., 2025).

International meta-analytic evidence is consistent with these conclusions. Structured, curriculum-embedded TPACK interventions reliably improve pre-service teachers' integrated knowledge and help advance practice beyond functional uses of technology, indicating that designed supports, rather than devices alone, drive classroom change (Fabian et al., 2024; Ramulumo et al., 2024). The unresolved question for this study is whether and how supervision and mentoring can raise usage quality in mathematics for student teachers placed in uneven rural and urban school contexts within ODeL, given the access and skills constraints identified above.

3.4 Institutional supports, programme alignment and the ODeL context

Ngoveni (2025a) highlights how policy clarity and targeted training shape staff and student confidence to use digital tools appropriately in higher education, particularly as teaching practice expectations increasingly include digital components for planning, communication, and assessment. Alignment between university coursework and field experiences is repeatedly emphasised in South African programme research, presented as necessary for ICT integration during teaching practice and for clarifying expectations for student teachers, mentors, and supervisors (Ngcapu et al., 2024). Mathematics-focused supervision work within ODeL identifies personalised feedback and reflective conferencing as practical designs that bridge geographic dispersion and subject-specialist constraints, while acknowledging limits created by uneven resources and variable mentoring capacity in schools (Mphahlele et al., 2024).

At the same time, the digital inclusion status of external supervisors signals capacity gaps and training needs that programmes should address if remote supervision is to be effective at scale (Age & Machaba, 2024). Internationally, placement geography shapes available mentoring and subsequent career intentions, strengthening the case for supervision and support that recognises contextual variation in school settings rather than solely individual dispositions (Fish et al., 2025). Across these strands, programme and policy design can mitigate the access, skills, and usage cascade by structuring supervision and support around reflective, mentored practice that is sensitive to rural and urban differences.

3.5 Synthesis and gap

Across the reviewed studies, material access, skills access, and usage are interdependent, and mentoring during teaching practice is the mechanism that links them. Rural placements face compounded disadvantages through weaker infrastructure and thinner mentoring, which depress skills development and constrain usage quality, while urban placements still depend on programme alignment and supervision quality to translate access into pedagogically meaningful practice. International evidence corroborates these structural drivers and identifies sustained professional learning as a primary means of shifting practice beyond functional use (Fabian et al., 2024; Hennessy et al., 2022). The study, therefore, addresses a specific gap: in mathematics-focused ODeL environments that place student teachers across heterogeneous schools, it examines how supervision and mentoring can be configured to counteract access constraints, support skills growth, and raise the quality of classroom usage in both rural and urban contexts.

4. Methodology

This section outlines the research design, case selection, participant sampling, data collection methods, and data analysis process employed in the study. It also explains how ethical considerations were addressed to ensure the study adhered to established research standards.

4.1 Research design

This study employed a qualitative multiple-case study design to explore how rural and urban student teachers experience and engage with digital technologies during their teaching practice within an Open Distance and e-Learning (ODeL) institution in South Africa. A multiple-case study design is particularly suitable for comparative research, as it allows for an in-depth exploration of two distinct contexts while preserving the unique experiences and challenges of each case (Yin, 2018). This design prioritises rich, context-dependent insights over statistical generalisation, making it appropriate for understanding lived experiences in complex educational environments (Creswell & Poth, 2018).

4.1.1 Case selection and description

The study focused on two distinct cases: Rural student teachers and urban student teachers. These cases were purposively selected to represent the geographical digital divide that shapes South Africa's educational landscape, particularly within ODeL systems.

- *Case 1, rural student teachers:* This case involved student teachers conducting their teaching practice in rural schools across the KwaZulu-Natal, Eastern Cape, and Northern Cape provinces. These schools are typically located in remote areas with poor digital infrastructure, including unreliable internet connectivity, inconsistent electricity supply, and limited access to digital tools. In this context, student teachers often relied on personal devices and self-funded internet access, with minimal institutional support for digital integration.
- *Case 2, urban student teachers*: This case focused on student teachers conducting their teaching practice in urban schools within the same provinces. These schools are located in better-resourced areas, providing high-speed internet, well-equipped computer labs, and a stable electricity supply. Urban student teachers benefited from structured digital training and increased institutional support, which allowed them greater opportunities to experiment with advanced digital tools in their classrooms. The comparative nature of the study allowed for an analysis of how geographical location shapes digital access, literacy, and engagement, thereby highlighting the contextual factors that contribute to the digital divide in teacher training.

4.1 Participant selection

Sixteen student teachers were purposively sampled from the University's College of Education, specifically from the pool of fourth-year students registered for Mathematics Teaching Practice.

Purposive sampling ensured the inclusion of participants who were: Enrolled as fourth-year students in the College of Education and completing teaching practice in either rural or urban areas. Student teachers from semi-urban areas and those in years 1 to 3 of their studies were excluded to maintain clear rural-urban contrasts. An open-ended questionnaire was distributed to 50 student teachers (30 rural and 20 urban), but only 16 responded (10 rural and 6 urban). Although the response rate was low, which may have led to potential response bias, with digitally confident students more likely to respond (Fowler, 2013), the qualitative approach ensures rich, contextually embedded data, even if generalisability is limited (Etikan et al., 2016).

The focus on Mathematics teaching practice was chosen because Mathematics is a core subject in the South African curriculum and plays a critical role in learners' progression across educational levels. Furthermore, the researchers' disciplinary expertise in Mathematics Education enabled a deeper analysis of subject-specific teaching practice experiences in relation to digital access, literacy, and technology use.

4.3 Data collection

Data were collected through a structured open-ended questionnaire designed to align with the Digital Divide Theory (Van Dijk, 2005) and the Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006). Participants were given two weeks to complete the questionnaire, which was distributed via their institutional email addresses using a secure online survey platform. This approach ensured accessibility for both rural and urban participants while maintaining the confidentiality of their responses. Moreover, it allowed for the collection of data that accurately reflected students' experiences with digital access, digital literacy, and the integration of technology into their pedagogical practices. The questionnaire included categorical items for demographics and placement context, as well as Likert-type items to capture access, frequency of technology use, and related perceptions (Likert, 1932). The Likert-scale items were designed to capture demographic variables, access to digital resources, and frequency of technology use in a structured, quantifiable format. These items complemented the qualitative responses by providing measurable indicators that could be compared across rural and urban cases.

4.4 Data analysis and ethical considerations

A manual thematic analysis was conducted following the six-step framework of Braun and Clarke (2006). This approach was selected for its flexibility and effectiveness in identifying patterns within qualitative data while accommodating theoretical perspectives from the Digital Divide Theory and the Technological Pedagogical Content Knowledge (TPACK) framework. The process began with familiarisation, during which all responses were read multiple times to ensure immersion in the data. During initial coding, meaningful text segments were identified and assigned descriptive codes reflecting participants' experiences, challenges, and strategies in using digital technologies. These codes were then organised into preliminary themes, representing recurring ideas across participants' accounts. Next, theoretical alignment was applied to ensure coherence with the Digital Divide Theory—focusing on access, skills, and usage—and TPACK—emphasising the integration of technological, pedagogical, and content knowledge. The themes were reviewed and refined to enhance internal consistency and distinctiveness. Given the study's comparative focus on ODeL mathematics, the final themes were presented case by case, contrasting rural and urban experiences before synthesising cross-case regularities. This theory-driven yet inductive process allowed new insights to emerge organically from the data. To ensure trustworthiness, a second researcher independently reviewed the coding and thematic structure, and discrepancies were resolved through collaborative discussion (Nowell et al., 2017).

The study adhered to the ethical guidelines of the University, with ethical clearance obtained under approval number 2021/11/10/90194969/41/AM. Participation was voluntary, and informed

consent was obtained from all student teachers. Anonymity and confidentiality were maintained throughout the process, and participants were informed of their right to withdraw at any stage without penalty.

5. Presentation of Results

This section presents the comparative analysis of rural and urban student teachers' experiences during teaching practice, structured according to the Digital Divide Theory dimensions of access, skills, and usage, and interpreted through the TPACK framework. The approach foregrounds contrasts and convergences across contexts, illustrating how infrastructural, institutional, and pedagogical factors intersect to shape the integration of technology. Participant identifiers use RS1–RS10 for rural students and US1–US6 for urban students; the secure mapping to raw responses is held by the researchers.

5.1 Access to digital tools

The most salient infrastructural disparity concerned internet reliability. Rural participants repeatedly highlighted the instability of network access. "*The MTN network was very poor… sometimes I could not even send emails or access online platforms*" (RS1), explained one participant from Bergville, echoing similar reports of intermittent institutional connections: "*Sometimes the internet disconnects, and I cannot download materials*" (RS2). Urban participants, by contrast, described continuous access to institutional Wi-Fi and university-provisioned data, which enabled real-time engagement with online learning platforms. "*We had Wi-Fi throughout the campus, and the institution provided data when needed*" (US1). This connectivity differential aligns with the first-level digital divide, illustrating how infrastructural availability directly shapes opportunities for developing technological knowledge (TK).

Beyond connectivity, frequent and unpredictable power outages further constrained rural placements, often rendering digital resources unusable at critical times. "*We experienced random schedules of power outages, making it impossible to rely on online teaching tools*" (RS3). In urban contexts, stable electricity supported the consistent availability of school-provided devices such as laptops and smartboards. Many rural participants relied on personal devices, self-funded routers, or single shared school computers: "*There was no access to a school computer, so I had to bring my own laptop and router to connect for learning purposes*" (RS4). Urban peers, meanwhile, reported institutional provisioning: "*The school gave me a laptop, and we had a fully equipped computer lab*" (US2), reflecting broader patterns of digital self-sponsorship among rural participants.

Institutional culture also played a gatekeeping role. In some rural schools, security concerns led to deliberate underutilisation of available technology: "*Computers were not present because the principal thought they would attract criminals*" (RS5). No comparable restrictions were reported in urban placements, where school leadership typically encouraged experimentation with technology.

These findings indicate that rural participants encountered intertwined infrastructural and institutional barriers that hindered their meaningful engagement with digital tools, whereas urban participants operated in more enabling environments that facilitated experimentation and alignment with TPACK's technological and pedagogical domains. These inequities form the foundation upon which subsequent disparities in digital literacy and classroom usage emerged.

5.2 Developing digital literacy through training and mentorship

Urban participants benefited from structured workshops, such as training on Google Classroom and interactive content creation, often supplemented by mentorship from technologically proficient colleagues. For example, one participant explained, "We had workshops on using Google Classroom and creating interactive content" (US4). In contrast, rural participants reported an absence of such opportunities, noting that "*Digital training should be part of our modules because technology is part of the*

new generation" (RS6). This absence reflects the second-level digital divide, where unequal access to structured training and mentorship perpetuates disparities in skills acquisition. Mentorship emerged as a key differentiator: *"I found a mentor who helped me learn how to use digital tools effectively"* (US5), shared one urban participant, underscoring how guidance and modelling facilitate more confident technology use.

Without comparable institutional or collegial support, rural participants often relied on self-teaching, navigating steep learning curves without formal guidance. As one participant noted, *"I had to figure out how to integrate technology into my lessons on my own"* (RS7). While urban participants also engaged in self-learning, their stronger baseline competence and mentorship networks reduced the cognitive and emotional burden of this process, enabling smoother incorporation of technology into lesson design and delivery. This contrast shows how access to professional learning mediates the transition from basic tool familiarity to pedagogically meaningful integration.

Across both groups, participants expressed a shared recognition of the need for ongoing digital-skills development. Rural participants prioritised training in interactive lesson design and basic troubleshooting: *"We need training on using smartboards, creating interactive lessons, and troubleshooting technical problems"* (RS8), while urban participants sought advanced skills in multimedia production: *"Workshops on multimedia creation, like making educational videos, would be very helpful"* (US6). All acknowledged the rapid evolution of educational technologies and the necessity of continuous professional development to remain pedagogically relevant, as one rural participant observed, *"Technology evolves fast, and we need continuous training"* (RS9).

These findings demonstrate that disparities in training access and mentorship lead to divergent developmental trajectories for technological knowledge within the TPACK framework. Rural student teachers, constrained by limited exposure and guidance, often entered classrooms underprepared for digital integration. Their urban counterparts, supported by institutional training and active mentorship, were better positioned to synthesise technological, pedagogical, and content knowledge into coherent practice. This divergence reflects van Dijk's conception of *skills access* as a critical intermediary in digital inclusion, emphasising the need for sustained, context-sensitive professional learning opportunities in teacher education programmes.

5.3 Engagement with digital tools in teaching

Urban participants demonstrated greater variety and pedagogical sophistication in their use of digital tools. They reported employing virtual simulations, multimedia resources, and interactive quizzes to support learner-centred instruction. One participant explained that they *used interactive tools such as virtual simulations, educational videos, and online quizzes to make lessons more dynamic* (US2), while another noted that *in mathematics lessons, PowerPoint and online games helped learners grasp fractions more easily* (US3). These examples illustrate how access to reliable infrastructure enabled richer pedagogical experimentation.

By contrast, rural participants, constrained by infrastructural limitations, relied on low-bandwidth solutions such as WhatsApp. This tool was primarily used for content distribution rather than for fostering interactive engagement. As one rural student teacher recounted, *they created a WhatsApp group because it was the only tool available for consistent communication* (RS10). Such practices demonstrate functional rather than transformative uses of technology, shaped by limited connectivity and access to devices.

Despite these constraints, rural participants exhibited considerable adaptability and creativity in resource-poor settings. For instance, one participant described substituting laboratory equipment with everyday materials, noting that *they brought glass containers from home and recorded the practical for learners* (RS2). Another explained how *using a phone camera to demonstrate experiments helped sustain learner participation when other tools were unavailable* (RS3). These efforts maintained the instructional

intent but rarely achieved full pedagogical integration, underscoring the influence of material access on the innovation of teaching.

Across both contexts, participants agreed that digital tools enhanced learner engagement. In urban placements, opportunities for such engagement were more frequent and structured. Participants observed that *learners became more attentive and enthusiastic when exposed to interactive technologies* (US4) and that *videos and online quizzes captured their interest and improved classroom participation* (US5). These reflections reveal a reinforcing relationship between teacher confidence, technological use, and learner motivation.

Overall, the findings highlight that the quality and depth of technology integration, the third level of the digital divide, remain context dependent. Urban participants tended to use digital tools in ways that supported transformative, learner-centred pedagogy, while rural participants' use was largely functional and constrained by infrastructural and skills barriers. This divergence supports van Dijk's (2005) view that access to usage is contingent upon prior levels of inclusion, aligning with TPACK's emphasis on the interdependence of technological and pedagogical knowledge. The results, therefore, call for context-sensitive interventions that extend pedagogical possibilities in resource-limited rural environments.

5.4 Proposed interventions for equitable technology integration

Participants' reflections revealed several targeted strategies for addressing inequities in technology integration during teaching practice. Central to these interventions was the need for structured, context-sensitive training opportunities that equip student teachers with both technical and pedagogical competencies. Rural participants emphasised foundational digital-skills development, *"We need training on using smartboards, creating interactive lessons, and troubleshooting technical problems"* (RS8), while urban participants expressed a desire for advanced workshops in multimedia production, *"Workshops on multimedia creation, like making educational videos, would be very helpful"* (US6). These views converge on the recognition that technology integration requires continuous professional learning to remain pedagogically relevant, as one participant noted, *"Technology evolves fast, and we need continuous training"* (RS9).

Beyond training, participants emphasised the importance of supportive mentoring and a positive institutional culture. Rural students identified limited guidance and restrictive policies as major constraints, with one remarking that *"Computers were not present because the principal thought they would attract criminals"* (RS5). Such findings underscore the need for school leadership that models and encourages digital engagement. Collectively, the data suggest that effective interventions must combine three mutually reinforcing components: (1) sustained digital-skills training, (2) mentorship that supports pedagogical application, and (3) institutional policies that enable equitable access to technological resources. Together, these address the infrastructural, skills, and usage dimensions of the digital divide, promoting more inclusive and transformative practices in teacher preparation programmes.

5.5 Cross-case summary

The comparative analysis reveals a persistent layering of digital inequalities: *infrastructural* (access), *skills-based* (literacy and training), and *pedagogical* (usage). These disparities are mutually reinforcing, positioning rural student teachers at a systemic disadvantage in developing the integrated competencies articulated in the TPACK framework. While rural participants' adaptive practices illustrate resilience, their reliance on self-sponsorship and low-tech solutions constrains opportunities for sustained innovation. Conversely, urban participants' enabling environments fostered more dynamic, learner-centred, and pedagogically integrated technology use. Participants' own recommendations, calling for structured digital-skills training, supportive mentoring, and leadership that values technology signal agency and a grounded understanding of how equity might

be achieved. Interpreted through van Dijk's successive access model, these insights confirm that material, skills, and usage access must be addressed concurrently. Together, the findings underscore that bridging the digital divide in teaching practice requires coordinated interventions linking infrastructure, capacity development, and pedagogical transformation.

6. Discussion of Findings

This discussion interprets the comparative findings through van Dijk's digital divide and TPACK, with theory woven into each theme rather than treated separately. A cumulative mechanism is evident: material conditions shape opportunities for mentored learning, mentored learning shapes skills, and skills determine whether classroom usage remains functional or becomes pedagogically integrated.

6.1 Material access: interpreting structural constraints

Rural placements were characterised by unstable networks, intermittent power, and scarce devices, which function as first-order bottlenecks in van Dijk's material access dimension. These constraints often forced rural participants into *digital self-sponsorship*, where they personally funded laptops, routers, and mobile data to sustain participation (RS4). Unlike their urban counterparts, who were provided with institutional Wi-Fi and laptops (US1, US2), rural students bore the responsibility of creating their own access, a pattern that shifts the burden of digital inclusion from institutions to individuals. Urban placements, by contrast, offered steadier connectivity and school provisions that widened opportunities for modelling and supervision, which explains why subsequent skill development was denser in those sites (Mphahlele et al., 2024). International evidence points to the same structural mechanism, as pronounced urban–rural disparities in teachers' digital environments are associated with differences in ICT competence elsewhere (Zhao et al., 2024). External supervision capacity forms part of this access equation because supervisors' own inclusion conditions the immediacy and quality of support in dispersed ODeL placements (Age & Machaba, 2024). The implication for teacher education is clear: placements and supervision should meet basic access thresholds if later stages of learning are to be feasible.

6.2 Skills access: mentoring and programme alignment as levers

Within van Dijk's skills dimension, mentoring serves as the proximal mechanism that converts exposure into operational and strategic literacies; where mentoring is lacking, students remain at tool familiarity rather than achieving pedagogical appropriation. In practice, rural participants reported having to *"figure out how to integrate technology into my lessons on my own"* (RS7), while urban participants described workshops on platforms such as Google Classroom and mentorship from colleagues (US4, US5). This contrast illustrates why mentoring density varied across placements, directly influencing whether students stayed at tool familiarity or progressed towards pedagogical appropriation. Alignment between coursework and fieldwork clarified expectations and accelerated growth in classroom-relevant skills, including resource selection, task design, and assessment, as evidenced in South African programmes (Ngcapu et al., 2024). Rural cases demonstrated how limited modelling and feedback restricted in-situ learning, a constraint consistent with reports of teaching-practice challenges in rural schools (Omodan, 2022). The skills pathway aligns with evidence from the ODeL study, where WhatsApp-mediated peer interaction and immediate feedback supported higher engagement and marked performance gains when activities were purposefully scaffolded (Ngoveni, 2025b). Reviews in low- and middle-income systems converge on the same mechanism, showing that sustained coaching, practice, and feedback matter more than hardware provision alone for teacher learning (Hennessy et al., 2022). Interpreted through TPACK, urban cases demonstrated movement from technological knowledge towards integrated decisions about pedagogy and content when mentoring and alignment co-occurred.

6.3 Usage: from functional demonstrations to integrated pedagogy

Usage differences align with van Dijk's third level. Under supportive conditions, student teachers progressed beyond functional demonstrations towards lesson-integrated applications; however, proficiency varied across cohorts and settings (Ramnarain et al., 2021). The findings revealed that rural participants often defaulted to low-bandwidth tools such as WhatsApp groups (RS10) or improvised with phone cameras to demonstrate lessons (RS3), while urban participants reported using multimedia and virtual simulations to support learner-centred instruction (US2, US3). In many rural placements, usage remained sporadic or demonstrative because time, infrastructure, and feedback loops did not facilitate iterative planning and reflection, a pattern evident in mathematics ODeL supervision reports (Mphahlele et al., 2024). Practical supervision features, including structured feedback cycles, reflective conferencing, and peer observation, were associated with more coherent planning and enactment in constrained schools (Pule et al., 2025). A recent meta-analysis explains why these designed supports matter, as curriculum-embedded TPACK interventions reliably strengthen integrated knowledge and help shift practice beyond tool use to conceptually oriented teaching (Fabian et al., 2024).

6.4 Cross-case integration: a conditions-to-practice pathway

Read across Sections 6.1 to 6.3, the pathway is cumulative. Material access determines the density of mentored opportunities; mentored opportunities broaden skills access; and the presence of integrated knowledge predicts whether usage is functional or pedagogically meaningful. A notable cross-cutting feature was "digital self-sponsorship," where rural participants had to bring their own laptops, routers, and even personal data to sustain their participation (RS4). This burden illustrates how structural inequality translates into individual responsibility, in contrast to urban participants who benefited from institutional provisioning. This dynamic exemplifies how structural inequality reappears as an individual burden, a mechanism that aligns with South African supervision evidence linking uneven provision to modelling and feedback constraints, as well as with international findings that locate the urban–rural disparity at the level of digital environments rather than individual disposition (Mphahlele et al., 2024; Zhao et al., 2024). The pathway identifies the design point for programmes, namely, to engineer mentoring and feedback where the infrastructure is weakest.

7. Conclusion and limitations

This study examined the digital divide faced by rural and urban student teachers in South Africa's ODeL context. The study answers its questions by tracing conditions to the practice pathway: material access set the bounds on mentored opportunity, mentoring widened skills, and integrated knowledge predicted whether classroom use remained functional or became pedagogically meaningful across rural and urban placements. It found that rural student teachers encounter infrastructural barriers, limited digital training, and restricted technology use, while their urban counterparts enjoy better access and structured training. These disparities illustrate how location affects digital opportunities in teacher education, with rural student teachers often needing to personally fund their access and develop digital skills independently.

The research introduces the concept of digital self-sponsorship, highlighting how structural inequalities place the onus of digital access on individuals. It emphasises the need for context-sensitive digital pedagogy training and mentorship, particularly for rural student teachers. The contribution is threefold: empirically, a Teaching Practice-specific comparative account of mathematics student teachers in an ODeL system; theoretically, an integrated explanation that links Van Dijk's dimensions with TPACK; and practically, a supervision template that aligns coursework with teaching practice, structures feedback cycles, and supports low-bandwidth task design and supervisor inclusion.

This study has some limitations that should be considered. The sample size was relatively small, as only 16 of the 50 student teachers who received questionnaires returned them, resulting in a low response rate that limits the generalisability of the findings. Additionally, the study relied on self-reported data, which may introduce response bias. Triangulation with observational studies or digital usage analytics could enhance reliability. Finally, this research focused on urban and rural contexts within specific geographic locations, and the findings may not fully capture variations in other regions. Expanding the scope to include different socio-economic and institutional settings would offer a more comprehensive understanding of digital disparities in teacher education.

7.1 Future research directions

To address the study's limitations, future research should expand the sample size and diversity to ensure broader representation across various regions and institutions, thus improving the generalisability of findings. Incorporating mixed-method approaches that combine qualitative insights with quantitative data would enhance the validity and depth of the analysis. Longitudinal studies tracking student teachers' digital literacy development and sustained technology use beyond teaching practice would provide insights into long-term impacts.

8. Declaration

Author Contributions: Conceptualisation (G.T.M, M.A.N & R.S.M); Literature review (G.T.M.); methodology (R.S.M.); software (N/A.); validation (R.S.M.); formal analysis (M.A.N & G.T.M.); investigation (G.T.M. & M.A.N.); data curation (M.A.N & R.S.M) drafting and preparation (G.T.M, M.A.N & R.S.M.); review and editing (G.T.M, M.A.N & R.S.M.); supervision (N/A); project administration (M.A.N); funding acquisition (N/A). All authors have read and approved the published version of the article.

Funding: This research is supported by the College of Education, University of South Africa, through the Open Distance Learning Research Support Programme (Grant number: ODL-RSP1). The Article Processing Charge (APC) was covered by the University of South Africa.

Acknowledgements: The authors make no acknowledgement.

Conflicts of Interest: The authors declare no conflict of interest.

Data Availability Statement: The data are not publicly available due to confidentiality agreements with participants. However, de-identified data can be made available from the corresponding author upon reasonable request, subject to approval by the ethics committee.

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