

Preservice teachers' integration of mobile technologies into early childhood science learning

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Abstract

The integration of mobile technologies into early childhood education presents promising opportunities; hence, this study examined how preservice teachers at a rural South African university utilise mobile technologies to support early science learning. Framed by the technological pedagogical content knowledge model, this qualitative case study investigated preservice teachers' perceptions, practices, and challenges during teaching practicum. Data were collected through semi-structured interviews and classroom observations with ten preservice teachers and were analysed thematically. Findings reveal that while preservice teachers recognise the potential of mobile technologies to enhance curiosity and active participation in science lessons, they do not see clear connections between technology use and child-centred pedagogy; their implementation is often constrained by limited access to devices and contextual barriers. The study highlights the need for targeted support and professional development to equip preservice teachers with the skills and confidence to effectively integrate mobile learning strategies into early science learning. The study contributes to the growing discourse on digital pedagogies in early childhood science education.

Keywords: early childhood education, mobile technologies, preservice teachers, science learning, teaching practicum, technological pedagogical content knowledge

INTRODUCTION

The integration of mobile technologies, such as tablet computers and smartphones, mediated by portable and wireless devices, plays a crucial role in transdisciplinary research and collaborative knowledge creation in teaching and learning (Lee & Ho, 2025; Pohl et al., 2021; Wang, 2024). This integration is characterised by the level to which technology is employed to improve the teaching of content in subjects such as science (Ateş & Garzón, 2022). It involves leveraging various technological resources within a learning context in a manner that is significant and aligned with educational goals (Bay, 2022). When preservice teachers are guided to employ educational technologies in teaching and learning that match learning objectives, that represents effective integration. In contrast, employing technology without a defined educational intent, such as watching unrelated videos, does not meet the criteria for integration (Wang, 2024). Remarkably, the integration of

mobile technologies into science education has proven to be effective as it enhances digital literacy, inquiry skills, retention of content, and engagement among young learners (Ateş & Garzón, 2022; Bay, 2022; Pohl et al., 2021; Wang, 2024).

Science education in the early years plays a critical role in helping learners make sense of the world around them (Papantonis Stajic & Nilsson, 2024). However, preservice teachers often face challenges in effectively teaching science content (Bay, 2022; Lippard et al., 2018). Studies indicate that greater consistency in science instruction across teacher preparation programmes can significantly enhance preservice teachers' confidence and preparedness to teach science (Akerson et al., 2018; Amaaz et al., 2024). One effective approach to strengthening their understanding involves integrating science concepts through transformative pedagogies, which have been found to improve both content knowledge (CK) and instructional skills (Lippard et al., 2018). However, external factors, such as the level of

Contribution to the literature

- This study advances research on digital pedagogy in early childhood education by exploring how preservice teachers integrate mobile technologies in science teaching.
- Conducted in the South African teacher education context, it offers contextually grounded insights into the interplay between digital access, pedagogical readiness, and systemic inequities in resource-constrained environments.
- The study extends the technological pedagogical content knowledge (TPACK) framework to early childhood science education, showing how developing teachers' technological, pedagogical, and content knowledge can promote inquiry-driven and child-centred mobile learning.

support provided by mentor teachers and limitations imposed by the curriculum, can affect the confidence and frequency with which preservice teachers incorporate these technologies in teaching science concepts (Akerson et al., 2018).

Generally, research on young learners' mobile learning experiences has reported a positive correlation between digital activities and their learning outcomes. For instance, learners who have more access to mobile devices than their counterparts perform much better than them (Mudra, 2020). Similarly, Neumann and Neumann (2017) found that early learning skills were developed in learners using touch screen devices as opposed to those who did not. Another study found that the digital environment plays a critical role in transitioning learners to be ready for learning because a more knowledgeable other helps them develop the skills needed for learning (Mudra, 2020). Moreover, learners' experiences with mobile devices influence their development of literacy skills and information and communication technology (ICT) (Arnott & Yelland, 2020).

Science education generally shares a similar academic structure and content worldwide; however, each country adopts distinct approaches to teaching the subject, shaped by its unique cultural and political contexts (Nikolopoulou, 2021). In this study, we consider the South African model of science education, which is found in the life skills subject. Life skills in the foundation phase (grades R-3) encompasses four distinct but connected topic areas, namely, *beginning knowledge, personal and social well-being, creative arts, and physical education*, to assist with learner development (Department of Basic Education [DBE], 2011). Beginning knowledge addresses social science concepts such as "conservation, cause and effect, place, adaptation, relationships and interdependence, diversity and individuality, and change", while natural science concepts deal with "life and living, energy and change, matter and materials; planet earth and beyond" (DBE, 2011, p. 8). Personal and social well-being addresses issues relating to "nutrition, diseases (including HIV/AIDS), safety, violence, abuse and environmental health" (DBE, 2011, p. 9). The incorporation of mobile technologies during this phase is seen as vital for

equipping learners for a rapidly evolving, tech-oriented society (DBE, 2020; Fullan & Langworthy, 2019;). As the 21st century classroom transforms, the proficiency of preservice teachers in effectively integrating technology is essential for promoting engaging and meaningful learning experiences (Van Wyk & Adeniji, 2021).

The use of technology in early childhood education goes beyond being just a teaching tool; it serves as a transformative pedagogical instrument that can change conventional teaching methods (Lee & Ho, 2025). Mdingi and Chigona (2021) asserted that educational technologies such as tablets, smartboards, and interactive software provide opportunities for tailored instruction, addressing the varied learning styles and developmental stages of young learners. For instance, animated programmes can reinforce literacy development, while educational applications (apps) can enhance numeracy and science skills (Maphalala & Adigun, 2021). Science education is particularly well-suited for technological integration due to its emphasis on social growth, physical education, health awareness, and artistic expression (Azadi, 2021; DBE, 2011).

Alongside skills and infrastructure, another significant issue is curriculum alignment. Some teachers struggle to connect their use of technology with the outcomes outlined in the curriculum and assessment policy statement. For example, the life skills (social and natural sciences) curriculum promotes hands-on and experiential learning, which does not always correspond well with activities that rely on screens (Joubert & Hartell, 2020). Teachers have reported feeling uncertain about how to effectively weave mobile technologies into their lessons while still maintaining the tactile, social, and physical aspects of early childhood education (Van Wyk & Adeniji, 2021). This conflict informs the necessity of context-sensitive strategies for integration that combine digital and traditional learning methods to uphold developmentally suitable practices.

Internationally, the incorporation of technology into early education is endorsed by frameworks such as UNESCO's (2021) ICT competency framework for teachers, which promotes digital literacy, pedagogical ICT utilisation, and lifelong learning abilities among educators. South Africa's national development plan (2030) also envisions an educational system that

leverages technology to enhance learning outcomes and foster equity (National Planning Commission, 2012). However, the practical realisation of these objectives in daily classroom activities remains complicated and necessitates ongoing investment, support, and policy alignment. Hence, this study aimed to determine how preservice teachers use mobile technologies to enhance engagement in early science learning in one rural university in South Africa. The aim of this study was explored through the following research questions:

1. How do preservice teachers perceive the role of mobile technologies in early childhood science learning?
2. How do preservice teachers integrate mobile technologies to promote engagement in science activities?
3. What challenges and opportunities do preservice teachers encounter when using mobile technologies in early science learning contexts?

THEORETICAL FRAMEWORK

The TPACK model is relevant to this study as it illustrates the intricate nature of teaching with technology by highlighting the interconnections between technological, pedagogical, and content knowledge. Additionally, this model has been broadened to incorporate contextual knowledge (XK), which recognises that successful technology integration is influenced by external elements such as school culture, policies, and infrastructure (Mishra, 2019). If the preservice teachers are confident in direct instruction (PK) in the science content area (CK), they can use TPACK to identify tasks that engage the use of technology. Then, they can use their expertise with information literacy to provide content-specific resources to enrich learning or suggest technological knowledge (TK) elements, such as a digital slide presentation, to build the technological competencies of learners. The teacher can lead learning on finding information using keyword searches online. They can provide the activity outlining required learning outcomes and create a visual slide presentation providing visuals for each of the physical features being investigated.

LITERATURE REVIEW

Use of Mobile Technologies in Early Childhood

Research highlights the importance of mobile technologies to enhance early childhood learning, particularly when used interactively and guided by adult facilitation. For instance, a systematic review by Neumann (2023) synthesised findings from 11 tier-1 and 4 tier-2 studies conducted in certain countries, including the United States, Australia, and the United Kingdom, involving children aged 2 to 6 years. The review found

that interactive mobile applications significantly improved learning (Neumann, 2023). In an Australian study focused on early science learning, Arnott and Yelland (2020) observed how tablets were used in four different early childhood education settings. Over 200 classroom episodes were analysed, where children worked in small groups or one-on-one with teachers. The study concluded that mobile technologies encouraged rich teacher-child interactions and led to deeper engagement with scientific concepts. These findings suggest that digital tools can facilitate inquiry-based learning and collaborative dialogue when integrated purposefully.

In addition, Van Wyk and Adeniji (2021) noted that students in schools where technology was consistently utilised showed increased engagement, particularly in subjects such as science, where visual and interactive resources assisted in clarifying challenging concepts such as personal safety and environmental consciousness. These insights demonstrate that, under suitable circumstances, technology can serve as a significant facilitator of enhanced learning in early childhood. Accordingly, Viberg et al. (2020) emphasised that mobile learning supports learning “anytime and anywhere”, nurturing continuous engagement beyond traditional classroom boundaries. For learners, this flexibility aligns with their exploratory and hands-on learning styles, while offering teachers a range of pedagogical possibilities (Kontkanen et al., 2022).

In another study in the United Kingdom, Kucirkova et al. (2014) explored the use of iPads for digital storytelling among preschoolers. Children aged 4 to 5 used drawing, voice recording, and sequencing tools to construct personal narratives. Although the study was not focused on science learning, it emphasised the value of mobile technology in supporting multimodal expression and identity construction, particularly among children with limited verbal communication skills. Nevertheless, instances of innovation and effective strategies using digital storytelling in the teaching of science were noted. Azadi (2021) found that digital storytelling science activities aided early learners in articulating their feelings, engaging in narrative thought, and expanding their vocabulary within an engaging setting. Likewise, Rahiem (2021) added that mobile technologies that combine storytelling with scientific content can deepen learners’ understanding and sustain their interest in scientific topics.

While mobile technologies offer various educational affordances, many scholars have cautioned against their overuse or misuse in early childhood education contexts. A prominent concern is the negative impact on behaviour and socio-emotional development. In a longitudinal study in Canada, Radesky et al. (2023) followed 315 preschoolers from the age of 3.5 to 5.5 and found that increased use of tablets was associated with greater emotional dysregulation, including frequent

tantrums, irritability, and impulsivity. These effects were more pronounced in children who used screens independently without adult guidance. Another constraint is the difficulty young children have in transferring knowledge from digital environments to the physical world. At Vanderbilt University, Strouse and Troseth (2014) made toddlers view a short instructional video to locate a hidden toy. Many failed to apply what they had seen, indicating that young children struggle with symbolic transfer unless they are actively engaged or guided by an adult.

Moreover, privacy and data security concerns have emerged as a significant issue. According to Livingstone et al. (2018), many educational apps aimed at children collect user data without adequate parental consent or safeguards, especially in low-regulation environments. This raises ethical concerns about the commercialisation of early childhood education through digital platforms.

Preservice Teachers' Use of Mobile Technology in Teaching Science

The integration of mobile technology into science education has garnered increasing attention, particularly in the context of preservice teacher training. Studies from diverse international settings highlight the challenges, affordances, and pedagogical implications of this integration, revealing a complex and varied landscape influenced by local contexts, educational systems, and technological access (Papadakis et al., 2020; Ramorola, 2022). Tondeur et al. (2012) found that while many teacher education programmes acknowledge the importance of digital integration, few offer sustained, practical experiences that allow preservice teachers to experiment with and reflect on technology use in real classrooms. In addition, Ramorola (2022) noted that many educators did not receive training in digital pedagogy during their initial teacher education programmes, and opportunities for ongoing professional development are often scarce and inconsistently available. This observation aligns with the findings of the DBE (2019), which recognised the necessity for a methodical approach to enhance teacher capabilities through its professional development framework for digital learning. Their pedagogical knowledge (PK) and digital literacy play a critical role in ensuring that technology supports, rather than replaces, active learning experiences (Nikolopoulou, 2022). This implies that intervention needs to target teachers' preparedness and provide hands-on experience.

A study in Germany provided insight into the belief systems of preservice biology teachers regarding digital media. The findings show that beliefs varied widely across different types of media, forming distinct belief profiles among participants (Funke et al., 2024). Another perspective comes from Morocco, where Amaaz et al. (2024) investigated the attitudes of preservice

elementary teachers towards integrated STEM education and the use of mobile devices. Preservice teachers were notably more receptive to the use of mobile devices within STEM contexts, especially among those with a scientific background. Additionally, Revák et al. (2024) found that digital activities and their impact have become increasingly prominent in early childhood STEM education. This points to the importance of not treating digital tools as a monolith in teacher training programmes. Instead, tailored, media-specific training could better support preservice teachers in selecting and applying appropriate tools for various instructional goals.

In Nigeria, Abdulazeez et al. (2024) explored the usability of mobile technologies among preservice biology teachers during their teaching practice. Their findings highlight a critical gap in technological literacy, which was primarily attributed to insufficient training during teacher education. Despite mobile phones being the most accessible and frequently used devices, the preservice teachers struggled to integrate them meaningfully into instructional delivery. Similarly, a study conducted in South African primary schools (grades 4-6), by Mogale and Jita (2025), found that although preservice teachers recognised the value of digital tools, their actual use of educational applications during work-integrated learning (which includes all subjects) was often limited by contextual constraints. These included a lack of digital infrastructure, inconsistent mentor support, and limited time to experiment with new methods. The authors advocated for more robust digital transformation strategies within teacher education curricula to bridge the gap between technological awareness and practical application.

In another South African study, Mangundu (2023) assessed preservice STEM teachers' e-readiness for online multimodal teaching. Utilising the adapted TPACK framework, the study revealed that while students generally held positive attitudes towards digital learning tools, they often lacked the confidence and competence to apply them effectively in real classroom scenarios. These findings reinforce the argument that positive attitudes alone are insufficient; confidence and practical, hands-on experience are essential for meaningful integration of mobile technologies into science instruction. This study was not based on grades R-3 teachers. Therefore, it is unclear how the preservice teachers use these mobile tools to teach science concepts, especially in early childhood education settings in the rural context in South Africa.

MATERIALS AND METHODS

Research Approach, Paradigm, and Design

This qualitative study is situated within the interpretivist paradigm, which prioritises

understanding the subjective meanings individuals assign to their experiences and actions within specific social contexts (Cohen et al., 2018). Interpretivism recognises that knowledge is constructed through interaction and interpretation, making it particularly suitable for research aiming to explore ways in which preservice teachers conceptualise and apply mobile technologies in early childhood science education. Given the context-specific nature of technology use and learner engagement, this paradigm supports the exploration of multiple realities and individual meaning-making in a rural university environment.

The study adopted a case study design, which enabled a comprehensive and contextually grounded examination of the phenomenon within a bounded system. In this case study, we were interested in how teaching and learning with mobile technologies unfold within the institutional and socio-cultural context of teacher education in early childhood education. Ethical issues and clearance were observed before the commencement of data collection. We applied for ethical clearance from the ethics committee of the University of the Free State.

Sampling Procedure

A purposive sampling strategy was employed to select participants who could provide rich, relevant, and informed insights into the use of mobile technologies in science teaching (Creswell & Creswell, 2018). Recruitment began with an open call for participation distributed through departmental communication channels. The call targeted preservice teachers enrolled in their fourth year of study. These students had completed the life skills module, which includes foundational science concepts relevant to early childhood education. They possessed prior experience in teaching or planning science lessons, either through coursework or during previous teaching practica, and had used mobile technologies as part of their instructional activities. At the time of recruitment, they were preparing for their upcoming teaching practice placement. From the responses received, the first ten preservice teachers who expressed clear interest and met the inclusion criteria were selected. The selection was guided by the principles of information-rich case selection, aiming to capture a range of experiences within the bounded context of one rural university. Their voluntary participation and interest in the study also suggested a degree of reflection and motivation that contributed to the depth and richness of the data collected. The sample included 10 preservice teachers (8 females and 2 males) aged between 21 and 25 years, who represented diverse linguistic and socio-economic backgrounds. This sample size was deemed appropriate for a qualitative case study, where the goal is not statistical generalisation but rather an in-depth

understanding of a phenomenon within its context (Cohen et al., 2018).

Data Collection Tools

Data were generated through semi-structured interviews and classroom observations. Semi-structured interviews allowed participants to articulate their experiences, perceptions, and challenges regarding the use of mobile technologies in teaching early science concepts. Classroom observations were conducted during teaching practice sessions to capture how preservice teachers enacted technology integration in real classroom settings. An observation schedule guided the process, focusing on lesson structure, learner engagement, pedagogical strategies, and the nature of mobile technology use. Field notes were taken to record contextual factors and non-verbal interactions that complemented the interview and observational data.

Trustworthiness

To enhance the trustworthiness and credibility of the findings, several validation strategies were employed. Triangulation was achieved by using multiple data sources (interviews and observations) to corroborate emerging themes and ensure a more comprehensive understanding of the phenomenon. Member checking was used to confirm the accuracy of interview transcripts and interpretations with participants. In addition, inter-rater reliability was ensured during data coding, as two researchers independently coded a subset of the data and discussed discrepancies until consensus was reached. An audit trail documenting all decisions and analytical processes was maintained to ensure transparency and dependability of the study.

Data Analysis

Data were analysed using thematic analysis guided by Braun and Clarke's (2019) six phases, which included familiarisation, coding, theme generation, reviewing, defining, and writing up themes. The integration of multiple data sources allowed for the cross-validation of themes, thereby strengthening the internal consistency and interpretive depth of the study. The identified key themes were

- (1) mobile technologies as catalysts for inclusive and conceptual understanding,
- (2) translating digital exposure into pedagogical practice,
- (3) bridging the gap between potential and practice, and
- (4) building capacity for digital pedagogy.

RESULTS

Table 1 presents a thematic overview of the study's key findings, illustrating how preservice teachers'

Table 1. Summary of results

Theme	Description	Illustrative quotations	Theoretical link (TPACK)
1. Mobile technologies as catalysts for inclusive and conceptual understanding	Preservice teachers viewed mobile tools as enhancing engagement, inclusivity, and conceptual understanding in early science learning through visual and interactive media.	"Mobile technologies play an important role in adding to learning and teaching ... different strategies accommodate other learners."	Demonstrates TK supporting CK through multimodal approaches that enable active meaning-making.
2. Translating digital exposure into pedagogical practice	Participants reported confidence in using digital tools personally but struggled to transfer these skills into teaching practice.	"I use mobile apps every day, but I'm not sure how to use them effectively in the classroom."	Highlights a gap between TK and PK, reflecting underdeveloped TPACK integration.
3. Bridging the gap between potential and practice	While recognising mobile technologies' potential for inquiry and collaboration, preservice teachers mainly used them for teacher-led instruction.	"I bring my own laptop and present slides or videos to the kids so learning can continue."	Reveals a lack of pedagogical content knowledge and application; technology is used to transmit rather than co-construct knowledge.
4. Building capacity for digital pedagogy	Participants emphasised the need for curriculum-based training, access to child-friendly devices, and ongoing support.	"We need to be trained in workshops on the integration of mobile technology with content."	Points to the necessity of strengthening PK and institutional structures that support TPACK development within teacher education.

perceptions and practices relate to the TPACK framework.

The themes reveal that while participants recognise the potential of mobile technologies to foster inclusive, engaging, and conceptually rich learning, their classroom application remains limited by a lack of pedagogical integration. The findings highlight the importance of developing preservice teachers' technological, pedagogical, and content knowledge intersections to promote inquiry-based, child-centred, and contextually responsive science education practices.

Theme 1. Mobile Technologies as Catalysts for Inclusive and Conceptual Understanding

Participants demonstrated a shared understanding of the transformative potential of mobile technologies in early childhood science education. They reflected on how devices such as smartphones and tablets can enrich teaching and learning processes by enhancing inclusivity, engagement, and cognitive growth. These views are consistent with research emphasising the pedagogical affordances of mobile learning in early childhood contexts (Maphalala & Adigun, 2021; Nikolopoulou, 2022). Participant 3 and participant 5 said the following:

Participant 3: It makes things easy for learning because it has global information that is up to date. Children who do not have access to technology at home will see it at school.

Participant 5: They help learners see what their teacher is teaching and hear it too. It helps children, even those from disadvantaged

backgrounds, get exposed to technology at an early stage.

Observation case 1 supported the above claims. In one grade 1 classroom, the teacher used a tablet to play a short video on *living and non-living things*. Regardless of background, learners engaged enthusiastically, pointing out examples from their own environments. The shared digital experience allowed learners from differing socio-economic circumstances to participate equally, illustrating how mobile devices can democratise learning access (Nikolopoulou, 2022; UNESCO, 2021).

However, challenges were also observed. Observation case 2 involved a lesson on *plant growth*, where two of the tablets malfunctioned. Learners sharing devices became disengaged, and the activity's inclusiveness was compromised. This instance highlights the fragility of digital inclusion, where insufficient resources and connectivity can inadvertently reinforce inequities (Mogale & Jita, 2025).

Mobile technologies were also perceived as instrumental in supporting differentiated instruction. Participant 1 emphasised their role in accommodating diverse learning styles:

Participant 1: Mobile technologies play an important role in adding to learning and teaching ... different strategies accommodate other learners.

Observation case 3 demonstrated this in a lesson on *objects that sink or float*. The teacher first used a mobile simulation showing materials interacting with water, then facilitated a hands-on experiment where learners tested real objects. Visual learners benefited from the animation, while kinaesthetic learners were engaged

through tactile exploration. This integration of digital and physical learning aligns with Van Wyk and Adeniji's (2021) argument that effective early childhood science pedagogy must engage visual, auditory, and kinaesthetic modalities.

Conversely, observation case 4 highlighted pedagogical challenges. A teacher attempting to use mobile videos to demonstrate the *water cycle* encountered technical difficulties switching between applications. The pauses disrupted the lesson's flow, leading to learner restlessness. Such incidents suggest that teacher digital competence significantly affects the success of technology integration (Mogale & Jita, 2025).

Participant 2 and participant 10 viewed mobile devices as naturally engaging tools that increase intrinsic motivation and scientific curiosity among young learners.

Participant 2: Mobile devices will help children to easily ... so this will be fun for them, and they will like learning through them.

Participant 10: It helps prepare children for the digital world they grow up in ... stimulates curiosity and engagement.

Observation case 5 illustrated this enthusiasm during a science lesson using an app that played animal sounds. Learners actively participated, eagerly identifying each animal and expressing excitement when they were correct. This aligns with findings by Neumann (2023) and Arnott and Yelland (2020), who argue that mobile learning can enhance motivation and retention through playful, interactive engagement.

Observation case 6 further demonstrated conceptual growth. After watching an animated video on the *water cycle*, learners independently drew and narrated the process, displaying improved understanding of evaporation and condensation. This supports Papadakis et al. (2020), who found that visual simulations in mobile learning environments help make abstract scientific phenomena tangible for young learners.

Nonetheless, observation case 7 revealed that prolonged screen exposure during an extended video session led to inattention and off-task behaviour. While mobile devices can sustain engagement, excessive or poorly structured use may reduce attention spans, reinforcing Arnott and Yelland's (2020) argument for balanced digital integration.

Theme 2. Translating Digital Exposure into Pedagogical Practice

Participants reported using mobile devices to enhance lessons through multimedia, interactive songs, and hands-on activities, reflecting a growing understanding of technological affordances.

Participant 1 and participant 10 reported using mobile devices primarily to show videos or images to support science instruction. They indicated:

Participant 1: I play a video in the class, for example, when I teach them about nutrition ...

Participant 10: I bring my laptop into class to show my children slides and video clips on the topic ... Afterwards, we will conduct our volcano explosion ... This hands-on learning experience helps them understand chemical reactions, develop curiosity, and learn science vocabulary.

These digital resources serve as visual and auditory scaffolds to help young children grasp abstract or unfamiliar concepts. For instance, participant 1 plays videos on nutrition, while participant 10 uses video clips of volcanic eruptions to precede hands-on experiments. This approach reflects Mishra and Koehler's (2006) TPACK theory, which suggests that combining verbal and visual information with technology enhances comprehension and memory, which is valuable in early childhood.

Observation case 8 confirmed that integrating video demonstrations with tactile experiments strengthened conceptual understanding and learner engagement. However, not all preservice teachers were able to apply digital tools directly with children. For example, participant 5 said the following: "*I use mobile apps every day, but I'm not sure how to use them effectively in the classroom.*" Participant 9 described using mobile technologies primarily for administrative and training purposes, such as submitting assignments or preparing teaching presentations. Observation case 9 revealed that while preservice teachers demonstrated confidence in technology for academic tasks, translating this fluency into child-centred, inquiry-based instruction remained challenging. This illustrates the need for structured guidance in digital pedagogical integration (Mogale & Jita, 2025).

Theme 3. Bridging the Gap Between Potential and Practice

Participants identified several barriers that impede effective mobile technology use, including learner-related, pedagogical, infrastructural, and developmental factors. Participant 1 and participant 2 shared concerns about children's unfamiliarity with mobile devices or, conversely, overconfidence leading to misuse. Participant 1 emphasised that some learners are not accustomed to using such devices and may quickly lose interest without guidance. She said:

Participant 1: Learners are not used to these mobile technologies, so they do not know how to use them ... It is important for learners to get training for these mobiles.

Participant 2 echoed this, noting that older learners may mishandle devices due to a false sense of confidence, while learners with barriers may fear breaking them. She indicated:

Participant 2: Most of the learners (grade 3) are now old, and they tend to think they know how to use the devices, then end up breaking them. Some of the learners with learning barriers ... will be afraid to use them because they will think they might break them.

These reflections point to the importance of gradual, scaffolded digital training for young learners (Neumann, 2023), alongside intentional classroom management strategies. Observation case 10 illustrated that some learners struggled with touchscreen navigation, requiring scaffolded support, while others became overly excited, disrupting lesson flow. Participant 7 echoed this: *"Learners get, uh ... too excited, making it hard for them to concentrate on their lessons."* This issue of distraction and overexcitement is a recurring challenge in literature on mobile learning in early education (Arnott & Yelland, 2020), where emotional regulation and self-discipline are still developing.

A significant number of responses (participants 4, 8, and 10) pointed to systemic challenges, such as a lack of devices, poor infrastructure, and unreliable electricity or Internet. Participant 4 highlighted the broader structural issue of low investment in educational technology, especially in public schools.

Participant 4: The most challenge is more about access, as we are aware of poor infrastructure ...

Participant 8 noted the impact of load-shedding on connectivity, a uniquely South African challenge that interrupts lesson continuity. She said: *"...the problem is that the devices may switch off or have no Internet connectivity issues due to the load-shedding we experience in South Africa."* Participant 10 dealt with a lack of school projectors by using a personal laptop, showing the extent to which student teachers must improvise in under-resourced settings.

Participant 10: ... I bring my own laptop and present slides or videos to the kids so learning can continue.

Observation case 11 demonstrates improvisation using personal laptops to continue lessons. These issues reflect what UNESCO (2021) describes as "digital inequalities" that hinder equitable access to educational technologies. Furthermore, Participant 9 noted that learners' STEM curiosity could outpace their cognitive and motor development, as observed during robotics-themed activities (observation case 12), supporting the need for age-appropriate digital content (Amaaz et al., 2024; Neumann, 2023).

Theme 4. Building Capacity for Digital Pedagogy

Participants emphasised that effective mobile integration requires access to resources, targeted support, and curriculum alignment, which are all essential to transforming digital potential into pedagogical practices. Various responses (participants 1, 4, and 10) pointed to the lack of adequate technological infrastructure in schools. Participant 1, though confident in using mobile technologies, cited resource shortages as a major constraint. She said, *"Give us resources; teachers like me... schools lack resources."* Participant 4 proposed that NGOs and stakeholders should support schools with child-friendly, app-enabled devices such as mini laptops and projectors.

Participant 4: ... provision of the projectors, mini laptops that will specifically have apps. NGOs can also play a role ...

Participant 10 highlighted the need for science-specific equipment to support hands-on digital learning experiences.

Participant 10: The government should provide schools with enough science equipment ...

Observation case 13 demonstrated that learners were more engaged when devices were available and functioning, illustrating the foundational role of infrastructure equity (UNESCO, 2021).

In another perspective, participant 2 and participant 9 advocated for the inclusion of mobile technology integration in the teacher education curriculum, particularly within science education modules. They stressed that preservice teachers need more than general ICT training; they need to understand how to integrate digital tools meaningfully into early science pedagogy. The following is what they said:

Participant 2: In the institutions, there should be specific modules that teach us how to use mobile technology in a classroom.

Participant 9: Mobile technology should be part of what is discussed in the curriculum development. Teachers should receive training in science education.

Observation case 14 showed that learners familiar with tablets navigated science apps independently, whereas novices required step-by-step guidance, confirming the developmental benefits of early exposure (Van Wyk & Adeniji, 2021). This aligns with Mogale and Jita (2025), who argue that mobile learning must be framed within pedagogical contexts, not treated as a separate competency. Participant 3 broadened the discussion by pointing to the need for early exposure to digital tools among children themselves, starting from grade RR. The participant argued that this foundation

would benefit both teaching and learning by building familiarity and reducing classroom adjustment challenges. She said the following:

Participant 3: The department of education should implement technology from as early as childhood development (grade RR) so that learners can be exposed to these at an early age to prepare themselves for a better future.

This reflects the developmental perspective found in Van Wyk and Adeniji (2021), where early engagement with tools supports the cultural and cognitive development of young learners.

Moreover, participants 6, 7, and 8 emphasised the need for ongoing professional development, including workshops on mobile integration and computer literacy. These workshops should focus on practical classroom strategies, digital content curation, and device management. They indicated:

Participant 6: To attend workshops for computer lessons and be taught how to incorporate tablets and computers in our teaching lessons.

Participant 7: We need to be trained in workshops on the integration of mobile technology with content.

Participant 8: Teachers' workshops should promote more use of mobile technology in early childhood science classrooms and equip teachers with the right tools, so they are more prepared.

Similarly, the DBE (2019) emphasises that capacity-building for early childhood educators is essential if technology were to be implemented confidently and appropriately. Participant 10 called for stronger government involvement in terms of equipment for science and digital learning resources. She said, *"I think the government should provide schools with enough science equipment so that the teaching and learning of science can be effective."* This points to the need for coordinated digital policies within education departments to ensure ethical, age-appropriate, and purposeful technology use (Arnott & Yelland, 2020). Additionally, participant 5 stressed that preservice teachers should be encouraged to actively use mobile technologies during training, not just learn about them. She lamented: *"Encourage student teachers to use mobile devices more to engage with learners."* This aligns with the practical learning experience advocated by Mishra (2019), not theory alone.

DISCUSSION

This study highlights preservice teachers' growing recognition of the pedagogical potential of mobile technologies in early childhood science education. Participants viewed mobile devices as tools that enhance

engagement, promote multimodal learning, and expand access to global scientific content, findings consistent with research positioning mobile learning to advance educational equity in under-resourced contexts (Mogale & Jita, 2025; UNESCO, 2021). Their emphasis on addressing technological disparities underscores the continued relevance of mobile technologies in promoting inclusive and future-oriented education in South Africa.

While preservice teachers demonstrated basic digital fluency and an appreciation of mobile tools as catalysts for curiosity and cognitive growth, their classroom use remained primarily teacher-directed. This limited application suggests a gap in their TPACK, particularly in the integration of technological tools with appropriate pedagogical strategies and science content. Although participants possessed TK, their ability to blend it effectively with PK and CK was limited. This aligns with Ateş and Garzón (2022), who observed that without a strong TPACK foundation, technology use tends to reinforce traditional, teacher-centred practices rather than promote inquiry-based or collaborative learning.

Structural and contextual barriers, such as inadequate digital infrastructure, limited device access, and load-shedding, further restrict implementation. Pedagogical challenges, including behavioural management and developmental appropriateness, also constrain effective integration, supporting Neumann's (2023) and Arnott and Yelland's (2020) call for scaffolded and age-appropriate digital engagement.

Participants' recommendations point toward strengthening institutional and curricular support. They proposed integrating mobile pedagogy into teacher education, ensuring access to child-friendly devices, and providing targeted professional development. These suggestions align with national and international frameworks (DBE, 2019; Viberg et al., 2020) advocating for systematic preparation of teachers to integrate technology meaningfully in early learning contexts.

CONCLUSION, LIMITATIONS, AND RECOMMENDATIONS

This study examined preservice teachers' integration of mobile technologies into early childhood science education. Findings indicate an increasing recognition of mobile tools as catalysts for equity, engagement, and digital readiness. However, their classroom application remains largely teacher-directed and constrained by structural and contextual barriers. The findings extend understanding within the TPACK framework, illustrating that preservice teachers' limited classroom integration reflects underdeveloped intersections between technological, pedagogical, and content domains. Enhancing TPACK within teacher education programmes could enable more constructivist, inquiry-

oriented, and developmentally appropriate digital practices in early learning contexts.

A stronger alignment is required between digital education policies and teacher preparation frameworks. Policies should prioritise equitable access to digital infrastructure, targeted professional development in mobile pedagogy, and sustainable models for integrating technology into early childhood education, particularly in under-resourced settings. Teacher preparation frameworks should incorporate curricula that provide opportunities for the practical application of mobile technologies.

The study's reliance on a single institution limits the generalisability of findings. Future research should employ multiple case studies or longitudinal approaches to examine how preservice teachers' digital knowledge translates into practice. Exploring in-service teachers' and learners' experiences with mobile-assisted science learning would further inform theory, policy, and practice in technology-enhanced early childhood education.

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