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Preparing Intermediate Phase pre-service teachers in an information and communication technology integration course for Education 4.0: A Technological Pedagogical Content Knowledge framework approach

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Background: This study, informed by the Technological Pedagogical Content Knowledge (TPACK) framework, focused on an information and communication technology (ICT) course aimed at preparing pre-service teachers to effectively integrate technology into their future teaching practices in the Intermediate Phase (IP).

Aim: This study aimed to explore the effect of an ICT integration course on student teachers' preparedness to incorporate ICT into future teaching practices.

Setting: This study was conducted at a university in Gauteng, South Africa, for a third year undergraduate Bachelor of Education module.

Methods: A basic qualitative design framed by TPACK. Data were generated through course observations, semi-structured and stimulated recall interviews, and document analysis of student assignments, and were analysed using the constant comparative method to code data and to move from categories to themes in ATLAS.ti 25 (Lumivero, LLC, Denver, Colorado and United States).

Results: Four themes emerged. The course: (1) enabled the application of ICT knowledge in pedagogical contexts; (2) created opportunities to enhance ICT skills; (3) supported pre-service teachers in overcoming challenges stemming from limited prior ICT knowledge; and (4) provided practical experience that prepared them to integrate ICT when teaching.

Conclusion: The course prepared third-year pre-service teachers to integrate technology into their teaching by developing ICT skills, pedagogical understanding and confidence through practical experience. Although limited prior exposure and unequal access remain, the course equips them to meet the demands of Education 4.0.

Contribution: The study informs how initial teacher education programmes can better equip pre-service teachers to integrate ICT and support quality education.

Keywords: Fourth Industrial Revolution; information and communication technology; ICT integration; Sustainable Development Goal 4; initial teacher education; pre-service teachers; Technological Pedagogical Content Knowledge.

Introduction

The Fourth Industrial Revolution (4IR) has intensified the need for Education 4.0 practices that meaningfully integrate information and communication technologies (ICTs) into teaching and learning environments, aligning with Sustainable Development Goal 4 (SDG 4) (Quality Education) (Carrim 2022; Mulyani et al. 2021). Despite the global shift towards technology-rich classrooms, many pre-service teachers lack confidence and practical competence to use ICT tools when teaching. They often struggle to understand the purpose of these tools, and do not possess the necessary digital literacy skills required to use them effectively and meaningfully in classroom contexts.

Historically, each industrial revolution has transformed education by introducing new technologies. The First Industrial Revolution leveraged steam power, followed by electricity-driven mass production during the Second Industrial Revolution (Mulyani et al. 2021). The Third Industrial Revolution introduced advances in information technology (Carrim 2022), while the current 4IR (also known as Industry 4.0) is driven by artificial intelligence (AI), automation, advanced data analytics and immersive technologies such as virtual and augmented reality (VR and AR).

Each industrial revolution introduces new technologies to the education sector, including AI and digital tools such as VR and AR. However, the integration of these technologies is not explicitly covered in pre-service teacher education programmes. Instead, pre-service teachers often learn to use these tools during their school practice after graduation (Admiraal et al. 2017). This highlights a gap in the preparation of pre-service teachers to use technology in pre-service teacher education courses.

Problem statement

Education 4.0 builds on the foundations of Industry 4.0 and emphasises technology-enhanced, data-driven and learner-centred teaching methods (Bonfield et al. 2020). This shift in educational paradigms requires teachers to move away from traditional, teacher-centred approaches and adopt more collaborative, interactive and multimodal teaching strategies (González-Pérez & Ramírez-Montoya 2022). Industry 4.0 directly impacts education by introducing new technologies that empower both teachers and learners, enhancing their capabilities and improving their technological readiness. The use of automation, coding and AI in teaching and learning transforms the delivery of education, aligning with the principles of Education 4.0 (Bonfield et al. 2020; González-Pérez & Ramírez-Montoya 2022).

United Nations Educational, Scientific and Cultural Organization's SDG 4 emphasises the importance of pursuing quality education (Elfert 2019), which supports the need to shift from a standard teacher-centred approach to one that is student-centred and technology-guided. This shift requires training for teachers, specifically incorporating technologies afforded by the 4IR to achieve quality education as set out by SDG 4.

Information and communication technologies in teaching practice requires certain skills and competencies, such as digital literacy, through understanding of how to include technology into teaching repertoire, which can be achieved by understanding how to utilise different ICT tools and resources to support diverse learning needs (Ghavifekr & Rosdy 2015; La Fleur & Dlamini 2022). Therefore, teachers must be well-equipped and prepared to integrate ICT into their teaching and learning practices to create exciting and interactive learning environments that promote learner collaboration and critical thinking.

In the South African context, the Department of Basic Education (DBE) acknowledges the increasing importance of teacher preparation programmes in equipping pre-service teachers with vital digital literacy skills (DBE 2021a, 2025b). While policy documents clearly indicate that teachers are expected to enter the profession with sufficient digital competence (DBE 2021a, 2021b, 2025a, 2025b), the DBE has yet to establish a comprehensive national framework outlining the specific digital skills and technological tools that teachers must master prior to entering the classroom. Consequently, digital readiness varies significantly across institutions.

The South African education system anticipates that pre-service teacher education courses will produce teachers who are digitally literate and capable of effectively integrating technology into their teaching practices (DBE 2021a, 2021b, 2025a, 2025b). However, many existing teacher education programmes often do not adequately prepare pre-service teachers to incorporate digital tools effectively and to respond to the demands of 21st century education (La Fleur & Dlamini 2022).

Compounding this issue is a systemic challenge driven by ongoing digital divides, unreliable technological infrastructure, and insufficient professional development in ICT, all of which hinder the effective ICT integration in South African schools. To address these challenges, it is crucial not only to recognise the barriers, but also to actively work towards realistic solutions that foster equitable access to technology. Strengthening the technology infrastructure is a vital first step alongside comprehensive ICT-related professional development programmes that provide opportunities for pre-service teachers to gain confidence in using ICT by improving their current ICT competency. These contextual barriers underscore the need for stronger, more structured and context-responsive ICT preparation within initial teacher education (ITE) programmes.

Research question, sub-questions, aim and objectives

In response to the need for teacher preparation programmes to equip pre-service teachers with the skills necessary to understand and effectively utilise technology, the guiding research question for this study was: *What is the effect of an ICT integration course on third year pre-service teachers' preparedness to incorporate ICT into their future teaching practices to achieve Education 4.0?* This main research question led to two sub-research questions: (1) *What do pre-service teachers learn about ICT integration for Education 4.0?* and (2) *How do pre-service teachers plan to implement what they learned in the course when using ICT in their teaching?*

This research aims to explore the effect of an ICT integration course on student teachers' preparedness to incorporate ICT into their future teaching practices to achieve Education 4.0. This research investigated the skills and knowledge pre-service teachers gain from a course on ICT integration and explored how pre-service teachers intend to implement what they had learned in the course when they teach using ICTs in the Intermediate Phase (IP).

Exploring Technological Pedagogical Content Knowledge as a framework for analysis

A central framework underpinning effective technology integration is Technological Pedagogical Content Knowledge (TPACK), derived from Shulman's concept of Pedagogical Content Knowledge (PCK). While Shulman (1987)

foregrounded the role of subject knowledge and pedagogic techniques, Mishra and Koehler (2006) expanded this to include Technological Knowledge (TK), later refining it into the TPACK model (Mishra 2019). Technological Pedagogical Content Knowledge comprises three interconnected knowledge domains (see Figure 1): Content Knowledge (CK), Pedagogical Knowledge (PK), PCK, Technological Pedagogical Knowledge (TPK), TK and Technological Content Knowledge (TCK), which together enable teachers to design context-specific, technology-enhanced learning experiences (Yeh, Chan & Hsu 2021). Content Knowledge refers to a teacher's expertise in their subject matter, while PK describes a comprehensive understanding of teaching practices (Mishra & Koehler 2006:1026); together, CK and PK become PCK, which focuses on teaching by combining pedagogy with subject-specific content. Technological Knowledge involves familiarity with both standard and emerging technologies, and TPK recognises how various technologies can improve teaching practice (Mishra & Koehler 2006:1027). Lastly, TCK involves using technology to develop and present content, often outside of formal education (Mishra & Koehler 2006; Yeh et al. 2021). These domains are part of the TPACK framework, which supports effective teaching and knowledge creation in specific subjects (Yeh et al. 2021) (see Figure 1). By employing this framework, teachers can analyse and enhance their integration of ICT in the classroom (Mishra & Koehler 2006:1046).

The framework is widely used to assess the readiness of both pre-service and in-service teachers to integrate ICT effectively (Yeh et al. 2021). However, challenges persist, including the need for subject-specific TPACK tools to support discipline-aligned integration (Luo & Zou 2024). In this study, the TPACK framework provides a valuable lens for examining the extent to which an ICT integration course influences pre-service teachers' preparedness to incorporate technology into IP teaching (Dzikite, Nsubuga & Nkonki 2017).

Literature review

Introduction to information and communication technology integration in education

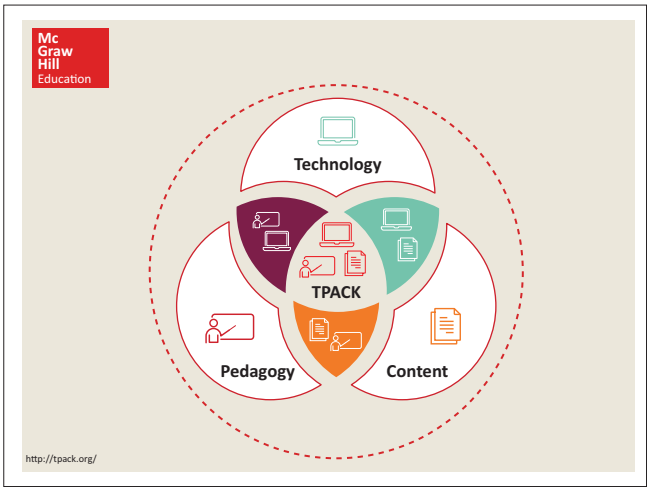
Effective ICT integration in education depends on teachers' understanding of digital literacy and their ability to apply technology in pedagogically meaningful ways. Digital literacy forms the foundation for confident ICT use, and teachers' attitudes towards technology significantly influence their willingness and ability to integrate it into teaching (Ghavifekr et al. 2014). Professional development is therefore essential, as it equips teachers with the knowledge and skills required to use digital tools effectively, thereby enhancing learner engagement and supporting instructional innovation (Ghavifekr & Rosdy 2015). For pre-service teachers in particular, ICT training plays a critical role in developing competence and confidence, enabling them to bridge the gap between theoretical understanding and classroom practice (Bueno-Alastuey & Villarreal 2021). Tondeur et al. (2018) further highlight how training methodologies shape ICT skills, emphasising that teacher education programmes must incorporate diverse learning strategies to align with Education 4.0 and SDG 4.

Challenges in information and communication technology integration

In the South African context, ICT integration is shaped by persistent urban–rural inequalities. The coronavirus disease 2019 (COVID-19) pandemic intensified the need for blended learning and exposed digital divides related to access to infrastructure, hardware and reliable electricity (Mwale, Nyamkure & Maluleke 2025). While urban schools generally possess stronger technological infrastructure (Batane & Ngwako 2017), ICT integration remains inconsistent and limited nationwide (Chigona & Chigona 2010; Mutisya 2020). As Taole (2024) argues, teachers' TK is essential for changing attitudes and improving ICT use in classrooms. Nonetheless, meaningful ICT integration requires both theoretical knowledge and practical experience, supported by relevant devices, reliable internet connectivity and ongoing professional development (Paidican & Arredondo 2022; Taole 2024). Nkula and Krauss (2014) caution against teaching ICT as isolated skills and advocate instead for curriculum-embedded integration. Yet many South African teachers still lack the necessary digital competence to utilise available resources effectively (Dlamini 2022), reinforcing systemic challenges in ICT adoption.

The importance of an information and communication technology course in pre-service teacher education

Information and communication technologies integration courses within ITE programmes, therefore, play a vital role in preparing pre-service teachers for technology-enhanced teaching. These courses provide structured opportunities to develop foundational ICT skills and apply them in pedagogically meaningful ways (Admiraal et al. 2017). Higher education institutions support this development by designing programmes that integrate technological pedagogical and content knowledge (Albion et al. 2015; Batane & Ngwako 2017). When implemented effectively, ICT courses promote creativity, enhance learner engagement and bridge the gap between theoretical instruction and classroom realities (Ghavifekr & Rosdy 2015). They also provide authentic contexts for practice and feedback, enabling pre-service teachers to refine their skills and develop confidence (Albion et al. 2015). However, gaps remain. Many pre-service teachers express a need for more subject-specific training and struggle to apply technical skills in real teaching environments (Mutisya 2020). Information and communication technology integration courses, therefore, serve a dual function: developing operational proficiency and fostering pedagogical reasoning about technology use (Batane & Ngwako 2017). Training must also address classroom-level constraints, such as ICT management and troubleshooting, which influence teachers' ability to integrate technology effectively (Maphalala & Adigun 2021).



Source: Mishra, P. & Koehler, M.J., 2006, 'Technological pedagogical content knowledge: A framework for teacher knowledge', *Teachers College Record* 108(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

TPACK, Technological Pedagogical Content Knowledge.

FIGURE 1: Technological Pedagogical Content Knowledge.

At the policy level, initiatives such as the National Plan for Higher Education and the White Paper for Post-School Education and Training underscore the importance of aligning teacher education with evolving ICT expectations (Department of Higher Education and Training [DHET] 2013; Maphalala & Adigun 2021). To enhance pre-service teachers' preparedness, programmes should extend the duration of ICT training, incorporate subject-specific content, and increase opportunities for practical application in classroom-like settings. A strong ICT foundation enables pre-service teachers to adopt creative, multimodal teaching strategies and supports their development as future-ready teachers.

An effective ICT integration course must therefore balance theoretical grounding with practical engagement (Bueno-Alastuey & Villarreal 2021; Mishra & Koehler 2006). Such courses should illustrate how technology enriches learning in key subjects, drawing on PCK to strengthen instructional design (Pamuk et al. 2015). Learning design tools – such as an Integrated Learning Design Environment (ILDE) – can foster flexible, diverse pedagogical approaches (Hernández-Leo et al. 2018). Progressive course sequencing, from initial exposure to hands-on practice and reflective evaluation, supports the development of techno-pedagogic competence (Gosain 2020). In addition, integrating devices such as smartboards, laptops and robotics kits helps connect theoretical concepts with real-world applications, promoting effective classroom technology use (Korucu-Kis & Ozmen 2019). Technology should complement traditional teaching methods and align with curriculum requirements to improve learner outcomes (Ghavifekr & Rosdy 2015).

Bridging information and communication technology theory and practice

Despite global and local advances in ICT integration, empirical evidence on the effectiveness of ICT integration courses in African ITE contexts remains limited. Urban–rural disparities and infrastructural challenges continue to shape pre-service teachers' experiences and capacities. This study, therefore, contributes by evaluating how an ICT integration course influences pre-service teachers' knowledge, skills and intentions, and by highlighting which course design features most effectively support transfer into real teaching practice. Many ICT courses still prioritise theoretical content at the expense of hands-on practice, resulting in a disconnect between technological understanding and pedagogical application (Aslan & Zhu 2015; Batane & Ngwako 2017). For courses to address 21st-century educational demands, they must incorporate emerging technologies such as VR, AI and machine learning (Bladergroen & Chigona 2019; Bonfield et al. 2020), as well as flexible pedagogical methods suited to diverse teaching contexts (Hernández-Leo et al. 2018). Practical assignments linked to teaching practice, combined with constructive feedback from mentors and peers, further strengthen pre-service teachers' readiness to integrate ICT (Admiraal et al. 2017). Through such a comprehensive design, ICT integration courses can build the competencies needed for technology-enabled teaching in the IP.

Recent advancements in teacher education have underscored the inadequacy of merely cultivating TK or conceptualising TPACK as a static system of technical skills for effective 21st century classrooms. Existing scholarship reframes TPACK as a dynamic, reflective process deeply rooted in didactic decision-making. Morales-López, Breda and Font (2024) found that a significant enhancement in pre-service teacher preparation occurs when a technological model, such as TPACK, is deliberately integrated with an educational framework. This purposeful collaboration encourages pre-service teachers to develop deeper reflective skills, allowing them to go beyond simply using digital tools on the surface. Instead, they engage in a thorough evaluation that considers subject-specific content, interaction dynamics and the appropriateness of technology for teaching purposes.

Given these insights, this study uses the TPACK framework to explore how an ICT integration course shapes pre-service teachers' preparedness to implement ICT in line with Education 4.0 demands, particularly in the South African context.

Research methods and design

This study was guided by the interpretivist paradigm, which conceives reality as socially constructed and best understood through participants' meanings and lived experiences (Shava & Nkengbeza 2019:247–248). Adopting this stance is appropriate because the study centres on how pre-service teachers experienced an ICT-integration learning environment and how they made sense of their preparedness to implement Education 4.0 practices. Accordingly, the study acknowledges multiple, context-dependent realities and positions knowledge as co-constructed through interaction with participants (Kivunja & Kuyini 2017; Ravitch & Carl 2021).

Guided by the understanding that reality is socially constructed and best understood through lived experiences, a qualitative approach with a basic qualitative design was employed to further explore how third year pre-service teachers interpret their experiences, perspectives and readiness to integrate ICT into future teaching. While the bounded context of a specific course and participant group displays characteristics comparable to an instrumental case study, a basic qualitative study was intentionally selected. This choice is justified because the primary objectives are not to analyse a bounded case but to rather understand the fundamental learning processes of the individual pre-service teachers within the course. In line with Merriam and Tisdell's (2016:62) view of qualitative design as a 'dynamic, systemic, and engaged process' that privileges context, this approach enabled fine-grained attention to participants' meaning-making processes and situated reasoning about technology use in classrooms (Merriam & Tisdell 2016; Ravitch & Carl 2021).

Setting

The study was set in a semester-long ICT integration module for third year IP pre-service teachers. The module comprised four units: (1) constructionism and Education 4.0 and SDG 4; (2) digital literacies (including AI literacies); (3) educational resource design (presentations, spreadsheets, websites); and (4) intersections of digital literacy with coding and robotics. Lectures ran across a 14-week semester with a 2-week Work Integrated Learning (WIL) block.

Participants and sampling

Participants were selected using purposive sampling. Purposeful sampling is used in qualitative research to provide in-depth insights from a specific population (Ravitch & Carl 2021:83). It involves selecting participants based on specific criteria such as experiences or knowledge (Palinkas et al. 2015). From the full cohort of students enrolled in the Teaching Studies 3A course (TEAST3A), a purposive sample of 15 participants was selected (attendance $\geq$80% and completion of all tasks), ensuring information-rich cases aligned with the study's aims and supporting qualitative saturation targets (Hennink & Kaiser 2022). This context anchors the interpretation of preparedness and supports cautious transferability to comparable ITE settings.

Data generation

Data for this study were generated through four qualitative methods: (1) 14 observations, (2) 30 student assignments, (3) 15 stimulated recall interviews and (4) 15 semi-structured interviews.

Observations

Observations provided firsthand insight into participants' learning experiences (Merriam & Tisdell, 2016:139; Ravitch & Carl, 2021:145–146) over the 14-week course and are dataset 1. In line with Goldkuhl (2019), to determine what pre-service teachers had learned, the observations were uncontrolled, in the natural setting of the course, (Mazhur et al. 2021:7), and therefore were used as a secondary source of data collection. Observations were internally collected and examined against the content covered and the learning outcomes, which were used to inform both the semi-structured and stimulated recall interviews.

Student assignments

Thirty student assignments were analysed using content evaluation and assignment rubrics, with relevant documents carefully screened and annotated to reveal both strengths and difficulties (Goldkuhl 2019:580). The assignments were the first and last assignments for the semester; these two assignments were selected as there were content similarities as well as an opportunity to improve their understanding through an iterative process (Khoza, 2013). For example, Participant 1 (P1) will have assignment 1 (A1) and A4 analysed, meaning that for 15 participants, their first and last assignments were analysed as dataset 3.

Stimulated recall interviews

Fifteen stimulated recall interviews were conducted to elicit participants' cognitive processes by having them reflect on their completed assignments and observation notes, the duration of which ranged from 20 min to 1 h. This is dataset 2. This method supports recall of decision-making during learning tasks and uses stimuli, such as marked assignments, to trigger accurate reflection (Gass & Mackey 2016:44–45; Goldkuhl 2019:580; Tondeur et al. 2013:435).

Semi-structured interviews

Fifteen semi-structured interviews followed a flexible, co-constructed questioning path that allowed probing and follow-ups (Karatsareas 2022), with all interviews' audio-recorded and transcribed to identify provisional categories and patterns within the data (Ravitch & Carl 2021:134). The duration for the semi-structured interviews ranged from 18 min to 1 h and 10 min. This is dataset 4.

Analytic strategy and trustworthiness

Data were analysed with ATLAS.ti 25 using the constant comparative method, moving iteratively from provisional categories to consolidated themes across datasets, with an explicit audit trail to enhance dependability and confirmability. Advanced AI-coding features were intentionally not used to maintain methodological alignment and researcher reflexivity in theme development (Dalkin et al. 2021).

Data analysis

This study employed the constant comparative method to analyse the data using ATLAS.ti.25 By comparing one data segment to another, the constant comparative approach was used to analyse the datasets (Merriam & Tisdell 2016:236).

The constant comparative method provides a structured way of producing significant results (Merriam & Tisdell 2016:203) and involves the steps below:

- Identify preliminary categories: I identified the categories based on the codes from each dataset while preparing the data and as I read through each dataset. Preliminary categories were derived solely from the literature review and observation notes; TPACK was not used to develop the initial codes. This is related to the study as it outlined the pre-existing themes surrounding the research, which were used to inform the formulation of the interview protocol.
- Coding the units of meaning: I analysed each dataset by highlighting the words, phrases or sentences relevant to the research question. These constituted the units of meaning. Each unit of meaning was assigned a code.
- Allocating the codes to the categories: After assigning codes to the units of meaning, I grouped them under the preliminary categories I had initially identified.
- Refining the categories led to the themes, which became the findings. In the final step, I refined each preliminary category and consolidated them into themes. The themes were used to present the findings (Table 1).
- Findings were then analysed and framed according to the TPACK framework (See Table 2, Table 3, Table 4 and Table 5).

Data were analysed using ATLAS.ti 25, a Computer-Assisted Qualitative Data Analysis Software (CAQDAS), following the constant comparative method to identify categories, compare patterns across datasets and develop the themes that addressed the research question (Figure 2). According to Dalkin et al. (2021) and Tisdell, Merriam and Stuckey-Peyrot (2025), CAQDAS refers to computer-assisted qualitative data analysis software used to organise, code, retrieve and audit qualitative datasets; in this study, ATLAS.ti supported systematic management of all datasets.

Figure 2 shows how the process unfolded from the preparation of data to the identification of the study's themes.

Table 1 demonstrates how the themes were derived from the refined categories from all datasets.

Quality criteria

Anonymity was maintained throughout the research, with personal information redacted from all data collected (Arifin 2018:31). Validity was confirmed through credibility (triangulation of multiple data collection methods), transferability (relevance to similar studies that focus on ICT integration), dependability (detailed documented processes) and confirmability (clear data analysis methods) (Ravitch & Carl 2021). Trustworthiness is essential for assessing a study's validity and quality and is defined by dependability, confirmability, credibility and transferability. Methods like triangulation can help establish it, emphasising the collaborative nature of knowledge construction and the need for researchers to reflect on their biases (Creswell 2013:300).

Ethical considerations

Ethical approval was obtained from a university in Gauteng (SEM1-2025-030), and gatekeeper permission was secured. Participants aged 18 years and older provided written consent and verbal consent before each interview was recorded. Confidentiality was ensured through the use of pseudonyms denoted as 'P.' Participants were informed of their right to withdraw from the study, and data will be stored for two years (Arifin, 2018, p. 30).

Ethical considerations refer to the principles that are in place to protect research subjects (Creswell, 2013). In this study, ethical clearance was obtained from the Institutional Review Board. Participants provided informed consent, and privacy was safeguarded using pseudonyms. Data retention followed approved time frames. Additionally, interviews were scheduled to minimise power dynamics and protect participants' academic standing.

This study adhered to rigorous ethical standards to ensure the privacy, anonymity, and confidentiality of all research subjects, in line with the university's code of conduct. Prior to the initiation of research, ethical clearance was obtained to ensure compliance regarding risk, consent withdrawal, and data access and storage.

Informed consent was acquired from participants, who were assured that participation would have no influence on their academic marks. Anonymity was upheld by redacting all personal information and assigning pseudonyms to each participant, denoted by 'P' (Arifin 2018, p. 30). Data collection methods included interviews, observation, and module assignments to enhance the reliability and credibility of the findings (Tisdell et al. 2025:288) while adhering to ethical standards.

Results

Themes

The following four themes were derived from the study:

- Theme 1: The course enabled pre-service teachers to apply ICT knowledge in pedagogical contexts.
- Theme 2: The course created opportunities to enhance pre-service teachers' ICT skills.
- Theme 3: The course supported pre-service teachers in overcoming the challenges that resulted from their limited prior knowledge of ICT.
- Theme 4: The course provided practical experience that prepared pre-service teachers to integrate ICT when teaching.

Discussion

While the TPACK framework (Mishra 2019) was used to interpret the findings, the main components identified from the findings above were TK and TPACK (Dzikite et al. 2017:63) (see Figure 3), which explained the effectiveness of the ICT integration course on third year pre-service teachers' preparedness to teach using ICT in

TABLE 1: Display of sub-questions, categories, themes and datasets.

Sub-questions	Categories in relation to the sub-questions	Themes in relation to the main question	Datasets
What do pre-service teachers learn from the course about integrating ICTs when teaching in the Intermediate Phase?	• Category 2.2: Pre-service teachers developed knowledge about using ICT for teaching and learning. • Category 3.1: Pre-service teachers gained both theoretical and practical skills for ICT integration. • Category 4.2: The course prepared pre-service teachers for 21st century teaching.	The course enabled pre-service teachers to apply ICT knowledge in pedagogical contexts.	Dataset 2 Dataset 3 Dataset 4
	• Category 1.1: Pre-service teachers learned to navigate various ICT tools to gain a deeper understanding of their function and use. • Category 2.3: Pre-service teachers technological knowledge increased. • Category 2.4: Practical skills in ICT applications were practised in various scenarios within this course. • Category 2.5: The ICT integration course boosted pre-service teacher's confidence through reflective engagement of their ICT abilities. • Category 4.3: Developed ICT application skills for the Intermediate Phase.	The course created opportunities to enhance pre-service teachers' ICT skills.	Dataset 1 Dataset 2 Dataset 4
	• Category 2.1: Pre-service teachers had basic knowledge related to ICT prior to attending the course. • Category 4.1: Limited ICT exposure challenged pre-service teachers' ability to complete assignments. • Category 4.4: Self-directed learning used by pre-service teachers to assist them in overcoming challenges.	The course supported pre-service teachers in overcoming the challenges that resulted from their limited prior knowledge of ICT.	Dataset 2 Dataset 4
How do pre-service teachers intend to implement what they learned in the course when they teach in the Intermediate Phase?	• Category 1.2: Practical applications of ICT tools were demonstrated and applied to various subjects in the Intermediate Phase. • Category 2.6: Effective integration of ICT in the course is dependent on the availability of structured support and sufficient resources. • Category 2.7: Pre-service teachers emphasise the use of emerging technologies to improve teaching and learning. • Category 2.8: The principles of SDG 4 aided pre-service teachers in understanding the practical impact of integrating ICT. • Category 3.2: Pre-service teachers plan to implement ICT through purposeful tool use and flexible strategies. • Category 4.5: Pre-service teachers are readily prepared to implement ICT tools in the Intermediate Phase. • Category 4.6: Hands-on experience is necessary in learning to integrate ICT.	The course provided practical experience that prepared pre-service teachers to integrate ICT when teaching.	Dataset 1 Dataset 2 Dataset 3 Dataset 4

Note: Main question: *What is the effect of an ICT integration course on third year pre-service teachers' preparedness to integrate ICT when teaching in the Intermediate Phase?*

ICT, information and communication technology; SDG 4, sustainable development goal 4.

TABLE 2: Technological Pedagogical Content Knowledge analysis of Finding 1.†

Descriptor	Quotation	TPACK analysis and commentary
The ICT integration course played a pivotal role in equipping pre-service teachers with the necessary knowledge and skills to effectively use technology in their teaching practice. Pre-service teachers developed a strong understanding of the ways that ICT can be used for teaching and learning. This foundational knowledge laid the groundwork for deeper engagement with technology in pedagogical settings.	'I gained much knowledge in this module. I had no knowledge and skills to effectively use technology in function[.]' (P1, Third year pre-service teacher, Male) 'I'm able to use AI. I am able to create websites, so I I didn't know how to do all of that so I could say requires a skill to create a website …' (P9, Third year pre-service teacher, Female)	Primary domain: TK These quotations reveal growth in TK. Participants moved from basic usage of ICT tools to mastering technical function such as the IF function in Excel. These quotations focus primarily on manipulation which is a vital prerequisite for future ICT integration.
As the course progressed, participants gained both theoretical insights and practical experience in ICT integration. This dual exposure enabled them to conceptualise and apply ICT techniques in purposeful ways.	'The SAMR model helps teachers integrate AI tools like Lumen5, ensuring meaningful rather than superficial adoption of AI technology.' (P3, Third year pre-service teacher, Female) 'A project can be to do a circuit on PHET simulation [,] and doing the project will enable the learners with the knowledge on how to do a circuit, and the same learner will be able to connect electricity in real life.' (P5, Third year pre-service teacher, Male)	Primary domains: TPK and TPACK This section reveals shift into the overlapping domains of the framework. P3 demonstrates TPK and TPACK: by combining the educational framework with a specific tool moving beyond basic technical execution to evaluate the pedagogical value of the technology striving for meaningful adoption.
Ultimately, the course prepared pre-service teachers to respond to the demands of 21st century Intermediate Phase classrooms. They emerged with a progressive perspective on how ICT can improve teaching and learning in diverse educational contexts.	'I would rate myself now at 8 because of the skills that I've acquired and the knowledge that I didn't have before attending the course.' (P2, Third year pre-service teacher, Female) 'I think that no, not that I think this course has prepared me in terms of a lot of aspects because now I know [*the content*].' (P12, Third year pre-service teacher, Female)	Primary domain: TPACK The participants quantitative self-assessment reflected the developed sense of technological pedagogy self-efficacy. This shifts the focus from isolated skill acquisition to internalised confidence, signalling readiness to implement integrated TPACK domains during teaching practice.

ICT, information and communication technology; SAMR, substitution, augmentation, modification, and redefinition; TPACK, technological pedagogical content knowledge; TK, technological knowledge; TPK, technological pedagogical knowledge; AI, artificial intelligence; PHET, physics education technology; P, participant.

†, Finding 1: The course enabled pre-service teachers to apply ICT knowledge in pedagogical contexts.

the IP. From the refined categories, four findings emerged and answered the main research question: *What is the effect of an ICT integration course on third year pre-service teachers' preparedness to incorporate ICT into their future teaching practices to achieve Education 4.0?*

Finding 1 indicates that the course enabled pre-service teachers to apply their ICT knowledge in pedagogical contexts. Finding 2 shows that the course created opportunities for pre-service teachers to enhance their ICT skills. Finding 3 reveals that the course supported pre-service teachers in overcoming challenges that resulted from their limited prior knowledge of ICT. Lastly, Finding 4 revealed that the course provided practical experience that equipped pre-service teachers to effectively integrate ICT into their teaching.

TABLE 3: Technological Pedagogical Content Knowledge analysis of Finding 2.†

Descriptor	Quotation	TPACK analysis and commentary
The excerpts come from the observations:		
The ICT integration course offered a structured and supportive setting for pre-service teachers to build their technological competencies, which are essential for modern teaching practices. Pre-service teachers began by learning to navigate various ICT tools, which helped them gain a deeper insight into their functions and potential uses in various educational contexts.	'Lecturers and students also explored essential techniques such as using Flash Fill, concatenating text with a double-click, and managing data formatting.' (Samuels observations, Week 8, Spreadsheets) 'Through various practical demonstrations, the student and lecturers explored how to generate relevant information and images using AI technology.' (Samuels observations, Week 8, Spreadsheets)	By learning specific operational features of software, pre-service teachers acquired real technical skills required to operate digital tools. Furthermore, exploring emerging software such as AI shows an expansion of the participants TK.
The excerpts come from the semi-structured interviews:		
As the course progressed, participants' technological knowledge improved, and they engaged in practical scenarios that allowed them to apply ICT skills meaningfully. These experiences were tailored to the Intermediate Phase, ensuring that the application was relevant to their future teaching contexts.	'So my knowledge went from an I'll say 30% to 80%.' (P8, Third year pre-service teacher, Male) 'Before, I was not able to use Excel, I was not really quite equipped with the skills of using the functions … I was able to do the Excel very, very quickly.' (P14, Third year pre-service teacher, Male)	There has been a measurable shift in the TK domain through self-assessment. The quantitative reflection from P8 as well as the transition of P14 highlights the progression from digital literacy to functional software fluency.
The excerpts come from the semi-structured interviews:		
The pre-service teachers developed ICT application skills relevant for the Intermediate Phase.	'I think assignment three it was more about the things that will be used in the classroom than just d[*efinitions*].' (P10, Third year pre-service teacher, Female) The excerpt below comes from a stimulated recall interview: '… The course has equipped me with the knowledge that I have now. If they were to give me a class today and ask me to teach this in that lesson, I would know what to do.' (P2, Third year pre-service teacher, Female)	The skills acquired are intended for future use in the Intermediate Phase, but the focus of this finding remains on mastering technological tools themselves for the Intermediate Phase age group. The specialised technological competency in developing ICT application skills addressed pre-service teachers TK and not general computer literacy.
Through reflective engagement with their ICT abilities, pre-service teachers gained confidence in using technology. This self-assurance was a key outcome of the course, empowering pre-service teachers to incorporate ICT more purposefully and effectively in their teaching. The ICT integration course boosted pre-service teachers' confidence through reflective engagement with their ICT abilities.	'… [*B*]efore attending the course, I thought it would be difficult. It gave me so much anxiety … but then after, I felt like it's something that it's not really difficult actually. I actually prefer using, I mean integrating these ICTs into teaching and learning …' (P3, Third year pre-service teacher, Female) 'I was never confident on the integration of ICT in the classroom to enhance learning. … I'm confident now because I know how to incorporate various tools.' (P8, Third year pre-service teacher, Male)	Overcoming the technical anxieties shows P3's transition from initial 'anxiety' to realising that technology can be easy indicating the individual TK self-efficacy. Similarly, P8 ties their newfound confidence directly to a technical milestone. The pre-service teachers solidified their foundational Technological Knowledge necessary to view themselves as component users.

Note: Primary domain: TK.

ICT, information and communication technology; TPACK, Technological Pedagogical Content Knowledge; TK, technological knowledge; AI, artificial intelligence.

†, Findings 2: The course created opportunities to enhance pre-service teachers' ICT skills.

TABLE 4: Technological Pedagogical Content Knowledge analysis of Finding 3.†

Descriptor	Quotation	TPACK analysis and commentary
The excerpts come from the semi-structured interviews:		
Many pre-service teachers entered the ICT integration course with only basic knowledge of technology, which posed significant challenges to their learning and performance. However, after attending the course, they were able to overcome those challenges. Pre-service teachers had limited exposure to ICT prior to attending the course. This lack of foundational knowledge made it difficult for them to engage fully with the course content and complete assignments effectively. Pre-service teachers had basic skills and knowledge related to ICT prior to attending the course.	'I didn't have any, you know, foundation about these kinds of things.' (P2, Third year pre-service teacher, Female) 'I don't think I was very confident because I had like very minimal knowledge and experience on it.' (P13, Third year pre-service teacher, Male)	Primary domain: low TK The critical gap in foundational digital literacy is demonstrated, and the data highlights knowledge which initially restricted the participants' ability to engage with ICT tools.
From the stimulated recall interviews, it was apparent that limited ICT exposure challenged pre-service teachers' ability to understand and complete assignments.	'The most challenging aspect was creating a website that was something that was completely new to me …' (P10, Third year pre-service teacher, Female) 'My first assignment was the most challenging … it was my first time encountering the hype cycle …' (P11, Third year pre-service teacher, Male)	Primary domain: TK exposure The focus here is the mastering of technology (mechanics and frameworks) itself rather than how to teach it.
Despite these initial difficulties, pre-service teachers demonstrated resilience by engaging in self-directed learning. This approach enabled them to gradually develop their ICT competence and navigate through the barriers posed by their limited prior experience and knowledge. Although they faced the aforementioned challenges, pre-service teachers utilised self-directed learning to help them overcome these obstacles. This was confirmed during the stimulated interviews with participants.	'… I never did a website before, but I was able to engage with platforms such as YouTube to get a quick tutorial …' (P5, Third year pre-service teacher, Male) 'I looked for like other lesson plans online and also like like 'cause. I didn't really know how to, create a lesson plan [*for coding*].' (P3, Third year pre-service teacher, Female)	Primary domain: TK Growth Participants moved from passive consumers with low TK to self-directed learners who can independently troubleshoot, acquire new technical skills and overcome their initial technical limitations.

ICT, information and communication technology; TPACK, Technological Pedagogical Content Knowledge; TK, technological knowledge; P, participant.

†, Findings 3: The course supported pre-service teachers in overcoming the challenges that resulted from their limited prior knowledge of ICT.

The TPACK framework has been adapted to make sense of the findings in this study. Figure 3 demonstrates that the findings account for pre-service teachers' TK (Findings 2 and Findings 3) and technological pedagogical content knowledge (Findings 1 and Findings 4), respectively, without necessarily being explicit about the other elements of the framework. This is the reason the framework was adapted.

Structural critique of the original Technological Pedagogical Content Knowledge model

This study critiques the original TPACK model, particularly in the context of short-term, intensive ICT courses (see Figure 3). While Mishra and Koehler (2006) present technology integration as a balanced interplay of TPK and TCK, these data reveal a different reality. In compressed ITE coursework, pre-service teachers

TABLE 5: Technological Pedagogical Content Knowledge analysis of Finding 4.†

Descriptors	Quotations	TPACK analysis and commentary
The ICT integration course offered hands-on opportunities that allowed pre-service teachers to engage with ICT tools in authentic teaching contexts. These experiences were instrumental in preparing them to integrate technology meaningfully in the Intermediate Phase. Pre-service teachers were introduced to practical applications of ICT tools, which were demonstrated and applied across various subjects in the Intermediate Phase. This hands-on experience was essential in helping them understand how and when to use technology effectively in real classroom settings.	'The learning task required students to explain how a particular AI can be used in a certain subject …' (Samuels Observations, Week 6, Ethical AI use) 'The outcomes for this lecture were that students selected any technological app or tool and created [*a Gartner Hype Cycle presentation*] …' (Samuels Observations, Week 3, Gartner's hype Cycle and PowerPoint presentations) 'The lecturers revisited each function applicable to the Teaching studies Assignment 3 and prompted students to [*practise complex calculations in spreadsheets*]' (Samuels Observations, Week 9, Excel techniques) 'They engaged students in exploring how coding and robotics can be utilised within the framework of Education 4.0 …' (Samuels Observations, Week 10, Developing computational thinking)	Primary domain: TPACK as Technological Knowledge (TK) leads towards Technology Content Knowledge (TCK) The acquisition of foundation TK is highlighted practical tasks like learning coding and spreadsheet calculations. Growth towards TCK is highlighted when participants align these technology tools with specific subject matters requirements
Pre-service teachers' hands-on experience was vital in enabling them to learn to integrate ICT. The following comes from the stimulated recall interviews.	'You may learn something, but without practice, you will not actually understand it. More so I, I, I think of them as these are all of all four assignments. I think of them as another way of not only assessment, but another way of learning. Because you actually get to practise what you have learned.' (P5, Third year pre-service teacher, Male) 'I think this was a very good approach is doing the lessons in the computer labs and we typing out all of our work that we do.' (P13, Third year pre-service teacher, Male)	Primary domain: TPK The pre-service teachers exhibit growth in TPK by reflecting on how a hands-on environment is not just about where you are using the devices; it alters the pedagogical approach transforming learning into experiential learning.
The assignments revealed the following:		
Building on this practical foundation, pre-service teachers began to plan for ICT integration by selecting purposeful tools and employing flexible strategies. By the end of the course, they felt well prepared to implement ICT tools and transfer their ICT knowledge in the Intermediate Phase.	'Introduction: Use a digital timeline tool like Timetoast or MyHistro … presentation: Use a multimedia presentation tool [*such as Prezi or Canva*] … consolidation: Instead of using paper exit tickets, use a digital assessment platform [*such as Kahoot!*] …' (P14, Third year pre-service teacher, Male) 'Gemini effectively bridges critical resource gaps. It empowers teachers to differentiate instruction [*and provides equal access*].' (P7, Third year pre-service teacher, Female) This was also confirmed in the stimulated recall interviews: 'If [*the lecturer*] were to give me a class today and ask me to teach this in that lesson, I would know what to do. Yeah, I would know what to do the methods to use and then tools to use.' (P2, Third year pre-service teacher, Female) 'This module made me try to get much knowledge on how to use the different technological tools for a teaching and learning … I imagine more, more, more confident and prepared, you know.' (P1, Third year pre-service teacher, Male)	Primary domain: TPACK. This highlights the full integration of TPACK. P14 and P7 show the gradual growth by purposefully mapping digital tools across different lesson phases to differentiate instruction and bridge the resource gap.
From the semi-structured interviews, the following insights were derived:		
Pre-service teachers also developed a broader understanding of the factors that influence effective integration of ICT. They highlighted the importance of structured support and sufficient resources. Additionally, they recognised the need to stay up to date with emerging technologies to enhance teaching and learning, and they connected their learning to the principles of SDG 4, which emphasise inclusive and equitable quality education.	'At schools, most schools, they don't have things like white boards and projectors, which makes it difficult …' (P10, Third year pre-service teacher, Female) '[*I*]t will depend if our schools in a more developed areas OK it will be easy for apply my skills of using [*ICT*] when teaching …' (P6, Third year pre-service teacher, Male)	Primary domain: TPACK. Growth is evident by the pre-service teachers shift from theoretical tools usage to the realities of contextual knowledge. The participants highlighted the infrastructure constrains and how school socio-economic issues impact the successful integration of ICT.
Pre-service teachers emphasised the use of emerging technologies to improve teaching and promote learning.	'… [*T*]he visual reality stood out for me and I can use it in a natural science classroom perfectly.' (P11, Third year pre-service teacher, Male) 'I learned about augmented reality.' (P1, Third year pre-service teacher, Male)	Primary domain: Intersection of TK and TPK. Learning about emerging tools represents expansion of TK. Growth into TPK is demonstrated by P11 realisation that a technological tool should have pedagogical utility.
The introduction of the principles of SDG 4 helped pre-service teachers understand the practical impact of integrating ICT:	'… [*I*]ntegrating ICT in like lessons in the intermediate phase kind of pushes us closer to achieving the or even achieving the goal of quality education.' (P2, Third year pre-service teacher, Female) 'SDG four is for education. It enables us to have quality education, to learn and to help us understand … then ICT, it helps student who is digital literate and technical skills, would be for the jobs that are currently ongoing …' (P9, Third year pre-service teacher, Female)	Primary domain: TPACK. Growth in the core TPACK domain is exhibited as pre-service teachers shift from looking at ICT as an isolated tool to understanding that ICT integration is a vehicle for driving meaningful, equity focused and future-ready pedagogical outcomes.

ICT, information and communication technology; TPACK, Technological Pedagogical Content Knowledge; TK, technological knowledge; TCK, technological content knowledge; TPK, technological pedagogical knowledge; SDG 4, sustainable development goal 4.

†, Findings 4: The course provided practical experience that prepared pre-service teachers to integrate ICT when teaching.

experience an imbalance in the development of technological-pedagogical reasoning.

Instead of progressing through overlapping domains like TCK or TPK, they make a direct leap from foundational TK to high-level TPACK frameworks, such as the substitution, augmentation, modification and redefinition (SAMR) model or alignment with SDG 4. This study expands understanding of TPACK by highlighting that the original framework oversimplifies the integration process, failing to capture the uneven, nonlinear pathways that pre-teachers actually navigate in practice-driven modules.

Development of technological knowledge

The course strengthened pre-service teachers' foundational and advanced ICT skills. This aligns with Mishra and

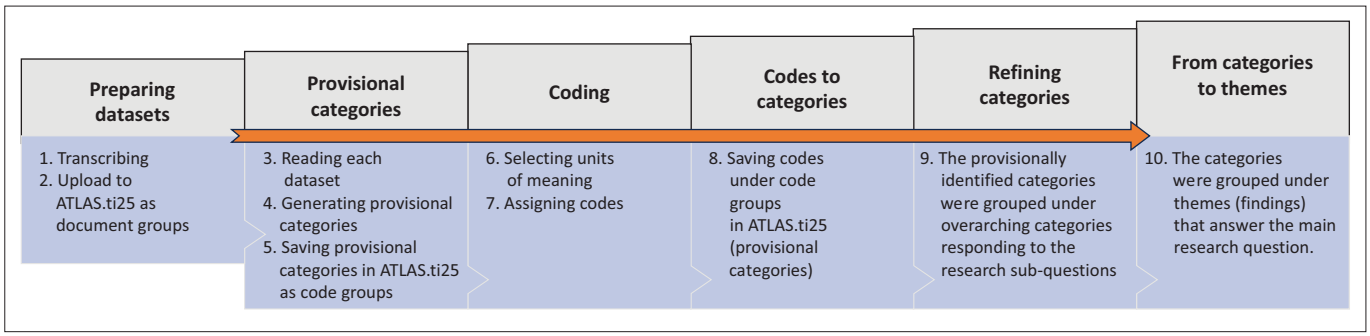
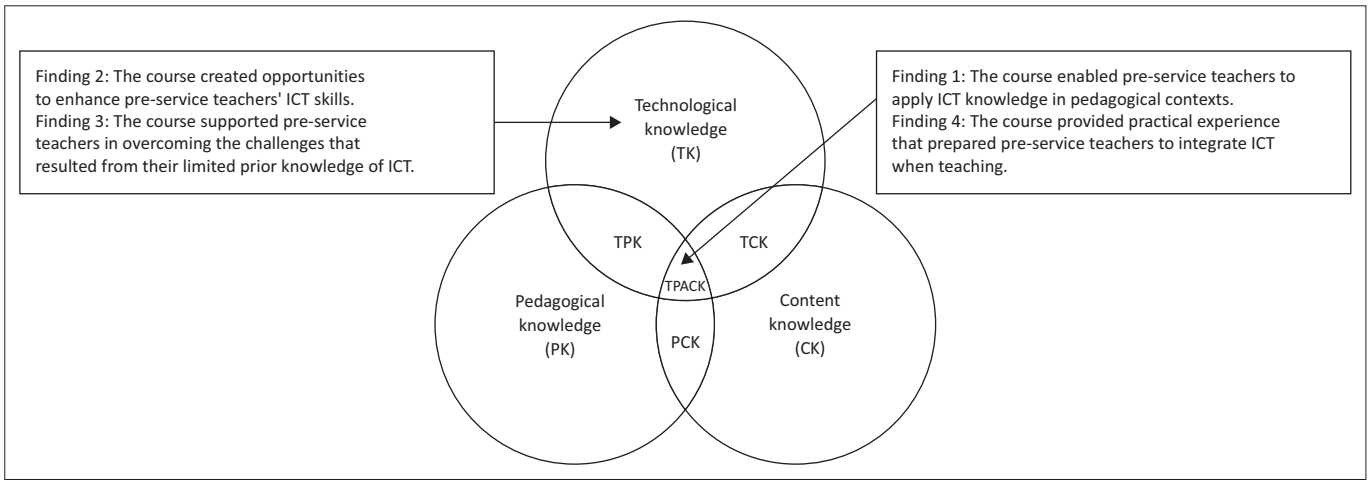


FIGURE 2: Overview of data analysis process using constant comparative method.



Source: Adapted from Mishra, P. & Koehler, M.J., 2006, 'Technological pedagogical content knowledge: A framework for teacher knowledge', Teachers College Record 108(6), 1017–1054. https://doi.org/10.1111/j.1467-9620.2006.00684.x

ICT, information and communication technology; TPK, technological pedagogical knowledge; PCK, pedagogical content knowledge; TCK, technological content knowledge; TPACK, Technological Pedagogical Content Knowledge.

FIGURE 3: Adaptation of the Technological Pedagogical Content Knowledge framework to illustrate the study's findings.

Koehler's (2006) conceptualisation of TK as knowledge of digital tools and their operations. Pre-service teachers progressed from novice to competent users of spreadsheets, AI, presentation software and coding platforms.

Consistent with Zhang's (2014) findings, structured ICT training supported the acquisition of literacy and functional skills, while reflective practice contributed to confidence and autonomy.

The findings of this study indicate that the compulsory ICT literacy course significantly enhances pre-service teachers' TK and skills. Mishra and Koehler's (2006) framework, alongside Yu and Golden's (2019) definitions, highlights the importance of both theoretical understanding and practical application of ICT in educational settings. Similar to Zhang's (2014) research, this course provided hands-on engagement through technology workshops, enabling pre-service teachers to develop critical skills for effective ICT integration in their future classrooms. These opportunities strengthened their confidence and readiness to utilise technology strategically in 21st century teaching contexts.

Despite these positive outcomes, the study acknowledges contrasting evidence from Aleksieva (2025) and Tondeur et al. (2020), which underscores ongoing inadequacies in ICT training for pre-service teachers. While mandatory courses exist, traditional pedagogical approaches often fail to provide adequate hands-on experiences and collaborative opportunities, resulting in gaps in ICT competencies. These contradictions highlight the necessity for diverse ICT training strategies, supported by knowledgeable facilitators, to foster effective integration of technology in teaching. Overall, the findings offer valuable insights into the critical role of structured ICT training in teacher education programmes, underscoring the need for continual improvement to meet the demands of modern educational landscapes.

The TPACK framework's neutrality assumption about pre-service teachers' initial skills is called into question by these findings. The model assumes that participants' TK is stable and widespread. This presumption, however, does not hold in settings like the South African educational system, which is characterised by systemic injustices and digital gaps. Many pre-service teachers have considerable gaps in their core TK when they enrol in teacher preparation programmes, necessitating a significant amount of course time for remedial skills.

Growth in Technological Pedagogical Content Knowledge

The findings demonstrate that the course helped pre-service teachers integrate technology with pedagogical reasoning.

Pre-service teachers increasingly aligned ICT tools with learner needs, curriculum requirements and subject-specific concepts. Practical activities, such as lesson redesigns and coding tasks, fostered the development of applied TPACK. This mirrors international studies (Gill, Dalgarno & Carlson 2015; Han, Shin & Ko 2017) showing that authentic tasks strengthen ICT pedagogical reasoning and improve future integration practices.

The findings indicate that the evaluated course significantly enhanced pre-service teachers' TPACK, equipping them with essential skills to integrate ICT into their teaching. The emphasis on practical experiences allowed these teachers to apply theoretical knowledge in authentic classroom contexts, thereby increasing their self-efficacy in utilising technology effectively (Han et al. 2017). This aligns with existing literature, which underscores the importance of hands-on engagement with ICT tools to foster effective teaching strategies and improve learning outcomes (Aslan & Zhu 2015, 2016).

However, challenges remain in translating theoretical learning into practical application. Qualitative findings revealed a disconnect between theoretical knowledge and real-world implementation, with many pre-service teachers feeling inadequately prepared to integrate technology despite their training (Niyibizi 2025). This highlights a critical gap in teacher education: While courses may offer foundational skills, additional emphasis on practical training is necessary to ensure that future teachers can confidently leverage technology in their classrooms, thereby bridging the divide between theory and practice in ICT integration.

Pre-service teachers in this study focus on mastering functional tools, such as Excel and AI-generated text, rather than on developing strong pedagogical reasoning. This issue reflects a broader trend noted in recent literature. According to Morales-López, Breda and Font-Moll (2023), to cultivate genuine techno-pedagogical reasoning, student teachers must learn to analyse how technology alters subject matter representation and student engagement with complex concepts. Without guided reflection on when and why to integrate these tools, technology remains a mere operational add-on (Morales-López et al. 2023:8) rather than a catalyst for meaningful learning.

The findings in this study present significant insights into the effects of an ICT integration course on third year pre-service teachers' preparedness to incorporate ICT into their future teaching practices, thereby addressing the main research question regarding achieving Education 4.0. The findings further indicated that the course enhanced both the TK and TPACK among participants. The third year pre-service teachers reported improved ICT skills, confidence and the ability to align technology with pedagogical practices, indicating a solid foundation for incorporating digital resources into their classrooms. The practical experiences throughout the course, although limited, allowed them to apply the theoretical concepts to real-world contexts, further solidifying their readiness for 21st century classrooms. Overall, the study highlights the vital role of structured ICT training in preparing future teachers to navigate and implement digital tools effectively, ensuring they are well equipped to meet the challenges and opportunities of Education 4.0.

Addressing gaps in information and communication technology skill variation

Pre-service teachers' initial lack of ICT competence presented a barrier to full engagement. However, through scaffolded tasks, lecturer modelling and independent learning, they overcame these limitations. The study confirms claims by Dağ and Doğan (2025) that structured exposure to ICT tools can close foundational gaps and build technological resilience. This suggests that ICT integration courses play a compensatory role, especially in contexts where digital inequality persists slightly.

Practical experience enhances readiness to teach in Education 4.0

Hands-on experiences enabled pre-service teachers to envision how ICT can support contemporary pedagogies. The course shifted its orientation from traditional teaching models towards technology-enhanced, learner-centred instruction aligned with Education 4.0. This echoes global research showing that opportunities for authentic, practice-based ICT integration significantly improve teachers' readiness for digital transformation (Admiraal et al. 2017; Kiili et al. 2016).

Furthermore, assessing pre-service teachers' preparedness within a university setting overlooks the constraints of real schools. Morales-López et al. (2023) note that pre-service teachers who consider teaching in technology-driven or virtual environments encounter unique factors, such as changes in learner–teacher interactions and emotional responses. In South Africa, where infrastructure issues magnify these challenges, teacher preparation programmes need to move beyond basic self-assessments. The study suggests incorporating structured micro-teaching, simulated lesson, and clear reflective frameworks to help pre-service teachers better understand real classroom constraints and align their confidence with their actual teaching practices (Morales et al. 2023:7–8).

Key findings and relation to prior work

The course's practice-oriented design strengthened both TK and TPACK, closing typical gaps between ITE coursework and classroom-ready integration. Participants' narratives and artefacts evidenced pedagogically principled use of ICT, aligning with the TPACK emphasis on content and learner-centred technology use rather than tool-led practice. The integration of theoretical frameworks such as TPACK, Education 4.0, and SDG 4, combined with scaffolded, hands-on tasks, seems essential for preparedness.

Strengths and limitations

Strengths include multiple data sources and rich triangulation across observations, interviews and graded assignments. Limitations include: (1) a single-institution sample (N = 15) within one module; (2) reduced contact time due to WIL; (3) outcomes assessed through course artefacts and participants discourse rather than externally observed teaching episodes, such as micro-lessons or simulated lessons; (4) reliance on the classic TPACK model without a deep contextual knowledge dimension in the updated TPACK model (Mishra 2019); and (5) the course-based evidence and self-assessment in confidence speak to preparedness to teach ICT in future classrooms rather than classroom implementation. This study primarily analyses perceptions of preparedness, intentions to use ICT and increased confidence.

Implications and recommendations

Course design should maintain a balance between theory and practice while increasing micro-teaching and simulations. This approach helps approximate real classroom enactments more closely and enhance feedback cycles, making ICT integration in pedagogical actions more evident. Add VR and AR sessions and subject-specific TPACK tasks to deepen transfer of learning. Support and resources must include sustained structured tutorial support around major assignments and provide low-tech pathways (e.g. unplugged coding, single-device projection) for resource-constrained placements. Assessment should be accompanied by complementary design artefacts with observed enactments (e.g. micro-lessons) to gauge integration moves, classroom orchestration and learner engagement. Extending analysis to contextual knowledge to the updated TPACK framework will enable nuanced planning for diverse resource profiles in South African schools.

Conclusion

The ICT integration course prepared third year pre-service teachers to integrate ICT into IP teaching by developing TK and TPACK through explicit theoretical framing and limited, scaffolded practical experiences. Preparedness is the perception of pre-service teachers regarding their use of ICT for teaching and learning, and their confidence in using ICT tools. Participants left the course more confident, with specific strategies for enacting Education 4.0 aligned to SDG 4, while acknowledging the importance of supportive structures and realistic adaptation to resource constraints. The findings provide a replicable blueprint for ITE programmes seeking to transform ICT competencies into classroom-ready practice. The results confirm that the ICT integration course was effective in enhancing pre-service teachers' readiness to integrate ICT in the IP. Their development across TK and TPACK domains demonstrates the importance of structured, practical and reflective ICT training within teacher education. The course addressed gaps in prior knowledge, fostered confidence and prepared pre-service teachers for teaching in 21st century learning environments aligned to Education 4.0 and SDG 4.

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During the preparation of this work, the authors used Microsoft Copilot and Grammarly to understand literature, simplify concepts, grammar, punctuation and summarise texts to a specific word count. The content was reviewed and edited by the authors, who take full responsibility for its accuracy.

Competing interests

The authors, Tatum A. Samuels and Kenneth Baloyi, declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

CRediT authorship contribution

Tatum A. Samuels: Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Validation, Visualisation, Writing – original draft, Writing – review & editing. Kenneth Baloyi: Conceptualisation, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Supervision. All authors reviewed the article, contributed to the discussion of results, approved the final version for submission and publication and take responsibility for the integrity of its findings.

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Data availability

The data that support the findings of this study are not openly available due to ethical and privacy restrictions. and

are available from the corresponding author, Tatum A. Samuels, upon reasonable request. De-identified data are retained securely for 2 years post-study in accordance with ethics approval.

Disclaimer

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