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Exploring ICT integration among Rwandan pre-service teachers: attitudes, barriers, and strategies

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Abstract

The integration of Information and Communication Technology (ICT) into teacher education is increasingly recognized as a catalyst for inclusive and future-ready learning environments. While global discourse on ICT in education continues to expand, empirical evidence from the Global South particularly concerning pre-service teachers in Rwanda remains limited. This study examines the ICT profiles, attitudes, challenges, and implementation strategies among 248 Rwandan pre-service teachers, with a focus on advancing equity in digital education. Utilizing a quantitative survey approach, the study provides nuanced insights into linguistic proficiency, access patterns, and ICT engagement. Results indicate that the majority of respondents are proficient in Kinyarwanda (98%) and English (85%), reflecting strong bilingual or multilingual capabilities. Inferential analyses reveal no statistically significant associations between gender and ICT training ($\chi^2 = 1.71$, $p = 0.19$), gender and desktop usage ($\chi^2 = 6.24$, $p = 0.10$), or residential location and ICT access ($\chi^2 = 3.21$, $p = 0.20$), suggesting equitable ICT opportunities across these variables. However, desktop usage differed significantly by age group (ANOVA $F = 263.91$, $p < 0.001$), with younger participants (16–24 years) demonstrating higher engagement underscoring the strategic importance of targeting this demographic in ICT-enhanced educational interventions. Despite widespread optimism about the pedagogical potential of ICT, respondents identified persistent barriers including limited infrastructure, insufficient digital tools, and lack of training. Nevertheless, a strong willingness to improve digital competencies was evident, alongside a shared recognition of ICT's transformative role in teaching and learning. The study calls for coherent policy frameworks, robust infrastructure investment, and targeted professional development to address systemic gaps and accelerate ICT integration in teacher education. These findings reinforce the strategic alignment with Rwanda's and Africa's broader aspirations to nurture a knowledge-based, technology-driven education system.

Keywords Information and Communication Technology (ICT) integration, Pre-service teachers, Technology adoption, Professional development, Rwanda



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1 Introduction and background

The integration of Information and Communication Technology (ICT) in teacher education is widely acknowledged as a critical factor in preparing pre-service teachers for the demands of contemporary classrooms [18]. In the 21st-century classroom, digitalization supports inclusive and learner-centered education, making it essential that teachers are equipped with appropriate digital skills [5]. Scholars such as La Fleur and Dlamini [10] and Esteve-Faubel et al. [4] emphasize that ICT is not merely a technological supplement but a strategic pedagogical tool that can improve student engagement and transform instructional practices. As Webb [22] notes, “while enabling new affordances and different ways of learning that are beneficial and motivating for students, developments in ICT were making the roles of teachers much more complex” (p. 277).

However, access to digital infrastructure alone does not guarantee meaningful ICT integration. Teachers need structured opportunities to develop digital-pedagogical competencies. Dlamini [2] argues that digital inequalities are reflective of broader systemic inequities, as disparities in access to digital tools and skills can exacerbate educational and social exclusion. Despite increased exposure to digital technologies, many pre-service teachers continue to report limited experience in using ICT for instructional purposes [4]. This study argues that contextualized professional development is necessary to ensure that teacher education programs do not leave future educators behind in the digital transition.

In Africa, and particularly in Rwanda, ICT integration in education is seen as a strategic priority to drive socio-economic transformation. Rwanda’s Vision 2020 and Vision 2050 position ICT as a central pillar in building a knowledge-based economy. The ICT in Education Policy [11] outlines national ambitions to enhance digital literacy, promote equitable access to digital tools, and improve teachers’ capacity to use technology effectively. However, Kwihangana [9] notes that implementation remains inconsistent, especially in rural or under-resourced schools due to infrastructural limitations and disparities in training quality.

Challenges of a similar nature have been reported across sub-Saharan Africa. In Lesotho, for instance, Thaanyane and Jita [18] found that pre-service teachers’ ICT integration capacity is shaped by personal self-efficacy, attitudes toward digital tools, and the level of institutional support provided. In these contexts, building ICT capacity among teachers is not only a technical requirement but a matter of equity and opportunity for learners. As such, providing access to ICT training during initial teacher education is essential to ensuring that future educators are capable of modeling and transferring digital skills in their classrooms.

Globally, teacher education programs are being restructured to address the growing need for digital competence. For example, Reisoglu and Çebi [14], as well as Taolane and Jita [17], report that many institutions are integrating ICT modules to help pre-service teachers gain technological, pedagogical, and content knowledge (TPACK). Yet, the quality of these programs varies. Vandeyar and Adegoke [21] emphasize that the success of ICT integration hinges on how well teacher training programs are designed and implemented. Zhang et al. [23] argue that structured, practice-based training is more effective than informal exposure to digital tools, particularly for developing global competencies in teaching.

Additionally, differences in pre-service teachers' attitudes toward ICT have been attributed to factors such as level of study, value beliefs, and self-efficacy [6]. Tomczyk [19], in a study conducted in Poland, identifies critical gaps in teacher education—particularly in areas like digital content creation, cyber security awareness, and the pedagogical use of learning analytics. Similarly, Mlambo et al. [12] found that while pre-service teachers in South Africa recognize the benefits of ICT in instruction, they often lack the practical training necessary for effective implementation.

Addressing these concerns requires a nuanced understanding of the realities faced by pre-service teachers from different institutions, subject areas, and socio-economic backgrounds. Their insights are crucial for informing program design, policy interventions, and professional development strategies. By exploring their ICT profiles, attitudes, challenges, and proposed solutions, this study aims to contribute to more equitable and effective approaches to ICT integration in teacher education.

1.1 Purpose and research questions

This study aims to examine the ICT competencies, perceptions, and challenges of Rwandan pre-service teachers, with a particular focus on equity and sustainable integration in educational practice. It also seeks to identify strategic interventions and professional development needs that can enhance digital inclusion and inform both policy and curriculum design. The study is guided by the following research questions:

- What is the current state of pre-service teachers' ICT knowledge in Rwanda?
- What are Rwandan pre-service teachers' attitudes toward ICT integration in education?
- What are the main barriers to ICT integration in Rwanda's teacher education sector?
- How can digital inclusion be effectively implemented in resource-constrained communities to transform pedagogical practices?

2 Theoretical background

This study adopts digital equity as its central theoretical framework to explore ICT integration in Rwanda through a multidimensional perspective. According to Dlamini [3], digital equity is achieved when all learners have equal opportunities to access and benefit from digital resources. In this context, the gap between pre-service teachers' positive attitudes toward digital pedagogy and their actual use of ICT reflects their level of exposure to and proficiency with digital teaching methods. Digital proficiency is therefore a crucial enabler of effective digital pedagogy. Digital equity is a key concept in understanding the pedagogical integration of ICT in teaching and learning. Rwanda continues to face significant digital equity challenges, which underscores the need for research to inform policy and practice within the teaching profession. Access to and affordability of digital devices and internet connectivity form the foundation of digital inclusion [16]. In the twenty-first century, digital devices and data access are essential for educational success. Amjad et al. [1] argue that “students with equitable access to technologically rich learning environments are better prepared to meet the challenges of the twenty-first century compared to those taught using traditional neomodern pedagogies” (p. 1). Aligned with the Education for All (EFA) movement, the Rwandan government is committed to achieving Sustainable Development Goal (SDG) 4, which aims to ensure equitable quality education for all.

Nevertheless, the absence of research-driven policy and practice can exacerbate existing inequalities in learners' experiences, leading to further digital disparities. This study contends that digital inequalities restrict learners' participation in the evolving information and communication technology landscape. As Dlamini [3] states, "the hallmark of educational equity is educational inclusion, social development, and economic mobility" (p. 194). To advance digital and educational equity, Rwanda must prioritize increasing access and equitable opportunities for all learners within the education system. The persistent challenges of quality and inequality in teacher education programs constitute what Dlamini [3] describes as a "wicked problem," often resulting in a "false start" to educational reform (p. 196). This study argues that technology-enabled education can play a transformative role by supporting educators in conducting regular assessments, interpreting data efficiently, monitoring learners' progress, and providing timely scaffolding to address diverse learning needs.

3 Literature review

3.1 Attitudes towards ICT integration

Pre-service teachers' attitudes toward ICT are a key determinant of their readiness and willingness to integrate technology into their teaching practices. Positive beliefs regarding one's digital competence significantly influence successful ICT adoption [15]. Similarly, studies from South Africa indicate that pre-service teachers generally view ICT as essential for improving instructional effectiveness and enhancing student engagement [12]. However, these attitudes are not uniform, they vary depending on pedagogical beliefs and the stage of teacher preparation.

For instance, Hülshoff and Jucks [6] identify two groups of pre-service teachers, those aligned with transmissive teaching philosophies and those who embrace constructivist approaches, each demonstrating varying levels of openness to ICT integration. This differentiation underscores the need for tailored ICT training that accommodates diverse teaching styles and belief systems.

Furthermore, active learning strategies such as project-based learning significantly enhance ICT integration skills by fostering deeper pedagogical competence [20]. Structured and professionally guided training programs are more effective in shaping positive ICT attitudes than informal or unguided exposure [23]. Collectively, these studies suggest that while attitudes toward ICT are malleable, they depend heavily on the nature and quality of training provided.

3.2 Barriers to ICT integration

Despite widespread recognition of ICT's potential, pre-service teachers encounter a range of barriers that hinder effective integration. One of the primary challenges is the lack of practical, hands-on training in teaching programs. This gap between theoretical knowledge and digital competence in real-world settings leaves pre-service teachers underprepared to confidently use technology in the classroom [8, 19].

Institutional and infrastructural limitations further compound these issues, particularly in under-resourced contexts. In Rwanda, for example, Kwihangana [9] reports a disconnect between policy aspirations and the limited availability of digital infrastructure in schools. Similar findings are observed in Lesotho, where inadequate resources and insufficient ICT training remain persistent obstacles [18]. These systemic constraints

suggest that policy efforts must be matched with tangible support and investments in infrastructure.

Self-efficacy also plays a critical role. Research shows a direct correlation between pre-service teachers' confidence and their likelihood of effectively integrating technology [23]. Guided practice and mentorship are key to developing this confidence. Observing and modeling the ICT practices of experienced educators has been shown to significantly improve digital competence [21].

3.3 Strategies for effective ICT integration

Overcoming these barriers requires comprehensive and targeted strategies. Enhancing ICT training through structured professional development, especially programs that simulate real classroom contexts, ensures that pre-service teachers acquire relevant, practical skills [7, 21]. Programs that involve lesson planning, teaching, and post-lesson reflection help bridge the gap between theory and practice.

Mentorship plays a pivotal role in reinforcing learning. Experienced educators modeling effective ICT integration foster both confidence and competence among trainees [21]. In addition, collaborative and peer-driven approaches such as project-based learning promote engagement with digital tools, enhance instructional capabilities, and encourage peer-to-peer support [20].

At the institutional and policy level, there is a pressing need to move beyond aspirational goals and toward actionable support. Although Rwanda's education policy framework emphasizes the importance of ICT in teacher education [13], Kwihangana [9] notes a persistent gap between policy and classroom realities, emphasizing the need for aligned infrastructure and curricula. Similar recommendations are echoed by Thaan-yane and Jita [18], who advocate for embedding practical ICT components into teacher education programs.

Finally, embedding ICT within constructivist pedagogies, particularly project-based learning has proven effective in fostering active engagement and meaningful integration of technology in instruction [20]. Constructivist strategies encourage pre-service teachers to design learning experiences that promote critical thinking and student-centered teaching through the effective use of digital tools.

4 Methodology

This study employed a mixed-methods research design to comprehensively investigate the integration of Information and Communication Technology (ICT) among pre-service teachers in Rwanda. By combining both quantitative and qualitative approaches, the study aimed to generate a deeper and more nuanced understanding of pre-service teachers' experiences, attitudes, and challenges related to ICT use in education.

A simple random sampling technique was utilized to select a total of 248 pre-service teachers from accredited teacher education institutions across Rwanda. This sampling method was chosen to ensure that each potential participant had an equal probability of selection, thereby enhancing the representativeness of the sample and minimizing selection bias. The sample size was determined based on the estimated population of pre-service teachers in Rwanda, ensuring sufficient statistical power for both descriptive and inferential analyses.

Data was collected through a structured questionnaire that included both closed-ended and open-ended items. The questionnaire was developed based on existing literature on ICT integration in teacher education and was reviewed by a panel of subject matter experts to establish content and face validity. To ensure the reliability and clarity of the instrument, a pilot study was conducted with 30 pre-service teachers who were not part of the main study. Feedback from the pilot was used to revise ambiguous items. The reliability of the quantitative items was assessed using Cronbach's alpha, with values exceeding 0.75 across major constructs, indicating satisfactory internal consistency.

The closed-ended items were primarily measured using a four-point Likert scale ranging from 1 (Never) to 4 (Regularly), capturing the frequency of ICT use, attitudes, and perceived barriers. The open-ended items aimed to explore deeper insights into participants' views and were completed via both printed forms and secure online submissions, depending on accessibility and participant preference.

Quantitative data were analyzed using SPSS Version 26. Descriptive statistics, including frequencies, percentages, means, medians, and standard deviations, were computed to summarize patterns in ICT access, usage, and perceived training adequacy. Inferential statistical tests such as ANOVA and Chi-square tests were applied to examine differences across groups based on demographic variables. Prior to analysis, necessary assumptions such as normality and homogeneity of variance were checked using standard procedures. Where appropriate, effect sizes (e.g., eta-squared for ANOVA) were reported to assess the practical significance of the results.

Qualitative data derived from open-ended responses were analyzed using thematic analysis, guided by the six-phase approach proposed. The process began with the researcher familiarizing themselves with the data, followed by generating initial codes, searching for recurring patterns, reviewing and refining emerging themes, and finally defining and reporting the key themes. An inductive coding approach was employed, allowing themes to emerge organically from the data rather than being predetermined. To ensure the credibility of the findings, a subset of responses was independently coded by a second researcher, and inter-coder reliability was assessed through discussion and consensus-building.

The thematic analysis resulted in the identification of six core themes: attitudes toward ICT, barriers to ICT integration, professional development opportunities, pedagogical adaptations, institutional and policy support, and implementation strategies. These themes offered rich, contextual insights into the lived experiences of pre-service teachers and served to complement and triangulate the quantitative findings.

5 Findings

This study revealed important insights into the demographic composition of Rwandan pre-service teachers and how these characteristics may relate to their experiences with and perspectives on ICT integration. Demographic data helps establish a foundational understanding of the participants' context, which is essential for interpreting their attitudes, competencies, and the challenges they face in adopting digital tools in education. Table 1 presents a summary of key demographic variables including gender, age, location, and teaching experience.

The demographic analysis reveals several important patterns that have implications for ICT integration among pre-service teachers in Rwanda. First, the gender distribution

Table 1 Demographic characteristics of participants

Category	Count	Percentage (%)
Gender distribution		
Male	153	61.69
Female	95	38.31
Age distribution		
16–20 years	55	22.18
21–25 years	182	73.39
26–30 years	34	13.71
31–35 years	7	2.82
Geographic distribution		
Rural	141	56.85
Semi-urban	81	32.54
Urban	26	10.48
Teaching experience		
Pre-service teachers without teaching experience (No)	128	51.61
Pre-service teachers without teaching experience (Yes)	120	48.39

shows a notable majority of male participants (61.69%) compared to females (38.31%). This gender imbalance may reflect broader enrollment trends in teacher education and could influence the level of digital access and confidence in technology use, as past studies have shown gender differences in ICT adoption.

In terms of age, the majority of pre-service teachers (73.39%) are between 21 and 25 years old, representing a youthful cohort likely to be more open and adaptable to digital tools. A smaller proportion of participants fall outside this range, with only 2.82% aged 31 to 35, suggesting that most are early in their professional careers and may still be forming their teaching philosophies and digital habits. Regarding geographic background, over half of the respondents (56.85%) come from rural areas, while 32.54% are from semi-urban settings, and only 10.48% from urban areas. This rural dominance indicates a significant digital divide challenge, as rural pre-service teachers often face limited access to ICT infrastructure and internet connectivity, which may hinder their digital skill development. Lastly, the data on teaching experience shows that approximately half of the respondents (48.39%) have prior teaching experience. This mix of experienced and inexperienced pre-service teachers provides a valuable perspective on how prior exposure to classroom environments might influence readiness and attitudes toward ICT use in teaching.

5.1 Attitudes towards technology integration

The results in Table 2 indicate that tablets ($M = 2.90$) and virtual reality tools ($M = 2.90$) were among the most frequently used ICT tools, with a majority of pre-service teachers reporting occasional to regular usage. Smartboards ($M = 2.70$) and interactive whiteboards ($M = 2.59$) also showed moderate usage, although notably high percentages of respondents reported never having used them (100% and 97%, respectively), suggesting significant variability in access. In contrast, tools such as laptops ($M = 2.03$), data projectors ($M = 2.13$), and AI tools like ChatGPT ($M = 2.01$) were used less consistently, despite their general availability in educational contexts. Surprisingly, laptops, which are traditionally common in digital education, showed only moderate regular use, potentially reflecting infrastructural challenges or lack of institutional emphasis on their use. The least utilized tools included desktop computers ($M = 1.93$), WiFi connectivity ($M = 1.90$),

Table 2 Attitudes towards technology integration

ICT tool	Occasionally	Regularly (%)	Rarely	Never (%)	Mean score
Tablet	62	33	44%	19	2.90
Virtual reality	60%	33	50%	25	2.90
Laptop	95%	78	39%	32	2.03
Artificial Intelligence (e.g., ChatGPT)	86%	61	48%	21	2.01
Data projector	81%	91	41%	37	2.13
Desktop computer	19%	67	63	19	1.93
Reliable internet connection (3G/4G+)	51%	85	22%	10	1.97
Reliable internet connection (WiFi)	76%	53	28%	11	1.90
Social media (WhatsApp, Facebook, X)	36%	21	8%	3	1.92
Reliable internet connection (Local Area Network or wire connection)	87%	71	40%	70	2.35
Smartboards	52%	76	40%	100	2.70
Interactive whiteboards	70%	68	33%	97	2.59%

Table 3 ICT access and training

Access Type	Yes	%	No	%
ICT Resources	94	37.90	154	62.10
Internet at Home	95	38.22	153	61.29

and social media ($M = 1.92$), with most respondents reporting rare or no use. This underutilization may reflect limited institutional connectivity and insufficient integration of digital communication platforms into formal training.

5.2 ICT access and training

Table 3 summarizes the extent of access to ICT resources and internet connectivity among pre-service teachers. The data shows that only 37.9% of participants reported having access to ICT resources such as laptops, tablets, or desktop computers, while a significant 62.1% indicated a lack of access to such tools. Similarly, only 38.22% of the respondents reported having internet access at home, whereas 61.29% lacked home internet connectivity. These findings highlight a substantial digital divide among pre-service teachers in Rwanda. The majority do not have consistent access to either digital tools or internet connectivity, which are critical for developing digital competencies and engaging in ICT-supported teaching and learning. This lack of access not only limits their ability to practice and apply ICT integration during their training but also raises concerns about their preparedness to use digital tools effectively in future classrooms. The results emphasize the urgent need for teacher education institutions and policymakers to invest in improving both infrastructure and equitable access to digital resources. Bridging this access gap is essential to promote digital inclusion and ensure all pre-service teachers are adequately equipped for 21st-century teaching environments.

5.3 Usage of various ICT tools in educational activities

Table 4 summarizes the frequency of usage for various ICT tools in educational activities, categorizing them into four groups: Never, Occasionally, Rarely, and Regularly. It shows that internet connectivity tools like WiFi, 3G/4G+, and LAN are most frequently used, while traditional tools like desktop computers and laptops have moderate and consistent usage. Social media platforms are also widely used. In contrast, emerging

Table 4 Usage of various ICT tools in educational activities

ICT tools	Never	Occasionally	Rarely	Regularly	Mean score
Social media (WhatsApp, Facebook, X)	3	36	8	221	2.88
Reliable internet connection (3G/4G+)	10	51	22	185	2.62
Reliable internet connection (WiFi)	11	76	28	153	2.48
Data Projector	37	81	41	109	1.99
Artificial Intelligence (e.g., ChatGPT)	21	86	48	113	1.92
Laptop	32	95	39	102	1.79
Desktop Computer	19	119	63	67	1.70
Reliable internet connection (local area network or wire connection)	70	87	40	71	1.67
Interactive whiteboards	97	70	33	68	1.59
Smartboards	100	52	40	76	1.57
Virtual reality	125	60	50	33	0.98
Tablet	129	62	44	33	0.88

Table 5 Professional development and training

Category	Yes	%	No	%
ICT Training in High School	184	74.19%	64	25.81%
Willingness for Follow-Up Activities	213	85.88%	35	14.12%

technologies such as virtual reality and artificial intelligence have lower adoption, indicating a need for increased access and training to enhance their integration into education.

The results show that social media platforms (WhatsApp, Facebook, X) emerged as the most frequently used ICT tools among pre-service teachers, with a mean score of 2.88, indicating regular integration into learning and communication. Internet connectivity, via 3G/4G+ ($M=2.62$) and WiFi ($M=2.48$), also ranked highly, underscoring its foundational role in accessing digital resources. Moderate usage was observed for data projectors ($M=1.99$) and artificial intelligence tools like ChatGPT ($M=1.92$), while laptops ($M=1.79$) and desktop computers ($M=1.70$) were used less frequently, possibly due to access limitations. Wired internet (LAN, $M=1.67$), interactive whiteboards ($M=1.59$), and smartboards ($M=1.57$) showed limited but notable use. In contrast, virtual reality ($M=0.98$) and tablets ($M=0.88$) were the least used, reflecting cost, limited infrastructure, or low familiarity. These results suggest strong reliance on mobile and internet-based tools, while the adoption of emerging and classroom-based technologies remains limited.

5.4 Professional development and training

Table 5 presents findings on participants' prior ICT exposure and their willingness to engage in further ICT-related activities. A substantial proportion of respondents (74.19%) reported having received ICT training during high school, indicating that a majority of pre-service teachers entered their training programs with foundational digital skills. This early exposure may play a critical role in shaping their confidence and preparedness for integrating ICT into pedagogical practices. In addition, a high percentage (85.88%) of respondents expressed willingness to participate in follow-up ICT-related activities. This suggests a strong motivation among pre-service teachers to enhance their digital competencies and engage in continuous professional development. These

Table 6 Language and communication skills

Languages	Read	Read, write	Speak	Speak, read	Speak, read, write	Speak, write	Write
Kinyarwanda	0	0	5	3	258	0	0
English	2	10	3	1	248	0	0
French	46	20	5	9	23	0	4
Swahili	24	32	6	5	78	1	3

findings point to both a promising baseline of ICT familiarity and a readiness to deepen engagement with technology in education through targeted support and training.

5.5 Language and communication skills

The results in Table 6 indicate that Kinyarwanda and English are the dominant languages among pre-service teachers in Rwanda. Specifically, the majority ($n = 258$) reported full proficiency in Kinyarwanda being able to speak, read, and write the language highlighting its central role as the national and most widely used language in education and daily communication. Similarly, English is widely mastered, with 248 participants indicating full proficiency. This aligns with Rwanda's policy of using English as the primary medium of instruction in schools. A smaller number ($n = 10$) reported being able to both read and write in English without speaking, suggesting that oral proficiency may still be developing in a few cases. In contrast, French and Swahili are less commonly mastered. Only 23 respondents reported full proficiency in French, while 78 indicated the same for Swahili. Notably, a significant portion of respondents reported partial competencies in these languages, for example, 46 could read French only, and 32 could read and write Swahili without speaking it fluently.

5.6 Inferential analysis across variables

The inferential statistical analyses conducted in this study aimed to explore associations between demographic variables (gender, age, and location) and ICT-related experiences among pre-service teachers.

First, the relationship between gender and prior ICT training in high school was examined using the Chi-Square test. The results yielded a χ^2 value of 1.71 with a p -value of 0.19, indicating no statistically significant association between gender and access to ICT training ($p > 0.05$). This suggests that both male and female pre-service teachers reported similar opportunities for ICT exposure during secondary education, reflecting gender-equitable access to digital learning experiences at the pre-tertiary level.

Second, an analysis of the association between residential location (rural, semi-urban, and urban) and access to ICT resources revealed a χ^2 value of 3.21 and a p -value of 0.20. This non-significant result ($p > 0.05$) implies that geographic location does not significantly influence pre-service teachers' access to ICT tools. The finding highlights a relatively uniform distribution of ICT access across different regions, which may be attributed to national policy efforts toward equitable ICT provision in teacher education.

In contrast, a comparison of desktop computer usage across age groups using one-way ANOVA produced a statistically significant result. The analysis returned an F-statistic of 263.91 with a highly significant p -value of $3.09\text{e-}44$ ($p < 0.001$), indicating that age significantly affects the frequency of desktop usage. Younger respondents (particularly those aged 16–24) reported higher levels of usage compared to their older counterparts, suggesting a generational trend in ICT engagement. This may reflect both higher

technological affinity among younger pre-service teachers and the increased integration of digital tools in recent educational curricula.

However, no significant association was found between gender and desktop computer usage, as shown by a χ^2 value of 6.24 and a p -value of 0.10 ($p > 0.05$). Both male and female participants reported comparable usage patterns of desktop computers, reinforcing the conclusion that gender is not a major determinant in ICT utilization frequency.

6 Challenges and opportunities in ICT integration

Analysis of the open-ended responses revealed several key challenges that hinder effective ICT integration among pre-service teachers. A commonly reported issue was inadequate ICT infrastructure, with participants highlighting the limited availability of essential tools such as desktop computers, projectors, and audio-visual equipment. This scarcity restricts the practical use of technology in teaching and learning activities. Another critical barrier was unreliable internet connectivity, especially in areas with unstable WiFi or mobile data networks, which significantly impedes access to digital content and real-time online communication. Furthermore, many respondents noted a limited supply of ICT devices, pointing to a mismatch between the number of students and the availability of functional tools, some of which were outdated or non-operational. A final but crucial challenge was the lack of adequate training, as several participants emphasized their need for more structured and ongoing support to develop the skills necessary for integrating ICT effectively into their pedagogical practices.

Despite these obstacles, the study also uncovered several promising opportunities. Many participants recognized that ICT could enhance learning experiences by enabling access to a broad range of educational resources and supporting more interactive and student-centered teaching methods. The integration of ICT was also seen as a pathway for digital skill development, equipping future teachers with the competencies required to thrive in technologically advanced classrooms. Additionally, ICT tools were valued for fostering collaborative learning, particularly through platforms like social media and cloud-based applications, which promote peer-to-peer engagement and support from instructors. Finally, respondents identified strong potential for improvement, expressing optimism that targeted investments in infrastructure and tailored professional development programs could significantly improve ICT usage and educational outcomes.

7 Discussion

This study provides nuanced insights into the integration of Information and Communication Technology (ICT) among pre-service teachers in Rwanda, revealing both promise and persistent challenges. While participants generally expressed positive attitudes toward ICT and acknowledged its potential to enhance teaching and learning, the study also uncovered substantial barriers that limit the practical realization of these aspirations. These findings are interpreted through the lens of the Technology Acceptance Model (TAM) and the TPACK framework, which emphasize not only users' perceived usefulness and ease of use but also their pedagogical knowledge and contextual readiness for technology integration. In this case, positive attitudes were often not matched by actual classroom implementation capacity, highlighting a gap between intention and practice that is influenced by infrastructural, institutional, and pedagogical factors.

One of the most significant findings concerns the limited access to ICT infrastructure and digital resources, particularly in rural teacher training colleges. While most pre-service teachers reported a desire to use ICT tools, many lacked access to basic devices such as laptops, projectors, interactive whiteboards, and reliable internet connectivity. These results align with earlier studies in sub-Saharan Africa, including Dlamini [3] and Kwihangana [9], who reported similar digital divides in teacher education contexts. In our study, the disparity between urban and rural access was particularly pronounced, reinforcing the need for targeted resource allocation. Opportunities for improvement, therefore, include investments in low-cost mobile devices, community-based ICT resource centers, and the expansion of offline-accessible digital learning platforms, which are more feasible in bandwidth-constrained areas.

A further critical issue is the disconnect between theoretical instruction and practical ICT training. While ICT components exist within pre-service teacher curricula, they are often delivered as content-heavy modules with minimal hands-on engagement. This mismatch limits skill development and undermines confidence in using technology in real teaching scenarios. This concern is echoed by Tomczyk [19], who observed in Tanzania that lack of hands-on practice created a gap between technological theory and classroom implementation. Similarly, Kanyinji [8] emphasized that without experiential learning, ICT training fails to produce competent digital educators. Our qualitative findings reinforced this concern, with participants repeatedly citing a lack of opportunity to practice with real tools during training sessions.

Moreover, internet connectivity emerged as a recurring constraint, particularly in rural institutions where inconsistent or nonexistent service severely restricts access to digital tools, online training modules, and emerging technologies such as artificial intelligence and virtual simulations. While it is tempting to view connectivity as a purely logistical issue, our findings underscore its broader implications for equity and access. As Stephens and Loble [16] argue, without substantial public investment in digital infrastructure, especially in remote and underserved areas, national ICT integration policies risk reinforcing rather than reducing educational inequality.

Despite these challenges, the study also uncovered important opportunities for fostering ICT integration. Many pre-service teachers expressed enthusiasm for continued learning and demonstrated openness to professional development initiatives. Such findings suggest a strong foundation upon which effective capacity-building efforts can be built. Promising strategies include online micro-credentialing programs, peer-led ICT learning communities, and low-tech blended training models that combine face-to-face workshops with mobile-based content delivery. These context-sensitive approaches align with recommendations by Vandeyar and Adegoke [21] and Tristiana et al. [20], who advocate for sustained, practice-based professional development embedded in authentic teaching environments.

Crucially, the qualitative themes uncovered in this study, such as professional growth, pedagogical adaptation, and implementation strategies, enrich our understanding of the quantitative results. For instance, while quantitative data showed moderate usage of tools like projectors and mobile phones, qualitative responses revealed how these tools are creatively repurposed to overcome resource limitations, such as using WhatsApp groups for peer learning and video demonstrations. These findings suggest that future

ICT initiatives should not only supply equipment but also support locally grounded innovations that reflect the adaptive strategies already in use.

Finally, comparing our findings with similar contexts reveals that these challenges are not unique to Rwanda. Research from Kenya, Uganda, and Ghana reports analogous constraints in terms of infrastructure, training, and curriculum alignment. This regional consistency highlights the importance of cross-country collaboration in designing scalable solutions that are both affordable and contextually appropriate.

8 Limitations

While the study offers important contributions, several limitations must be acknowledged. First, the reliance on self-reported data introduces the possibility of social desirability bias, whereby participants may have overstated their positive attitudes or downplayed challenges to align with perceived expectations. Second, the study's sample was limited to a specific cohort of pre-service teachers, which may affect the generalizability of the findings across different institutions and regions in Rwanda. Finally, the study did not include observational or performance-based data, which could have provided a more objective assessment of actual ICT competency and usage. Future research should consider mixed methods approaches, including classroom observations or digital competency assessments, to provide a more comprehensive picture of ICT integration practices. Additionally, longitudinal studies could offer insights into how pre-service teachers' ICT skills and attitudes evolve once they transition into the teaching workforce.

9 Conclusion

This study highlights not only the transformative potential of Information and Communication Technology (ICT) in teacher education but also the persistent, systemic barriers that hinder its effective integration among Rwandan pre-service teachers. While participants demonstrated strong motivation to adopt digital tools in their future classrooms, critical limitations including inadequate infrastructure, insufficient practical training, and unreliable internet access undermine their readiness and capacity. These challenges reflect a broader disconnect between national ICT policy aspirations and the operational realities within teacher training institutions.

Importantly, the findings suggest that ICT integration must be approached as a long-term capacity-building process rather than a one-time intervention. Success depends on a coordinated strategy that begins with foundational investments in infrastructure, followed by embedded, practice-oriented professional development, and sustained institutional support. These layers of intervention should not operate in isolation; rather, they must be aligned with national curriculum reforms and supported by a clear implementation and monitoring framework that tracks progress and responds to local needs. Moving forward, the study calls for a shift in focus from policy rhetoric to evidence-based, context-sensitive action. Ensuring equitable access to ICT resources, especially in rural institutions, must be treated as a priority. Moreover, fostering digital pedagogical skills requires continuous mentorship and peer collaboration, not just formal training. By addressing these interconnected dimensions, Rwanda can better equip its future educators to integrate technology meaningfully and lead pedagogical innovation in diverse and resource-constrained educational environments.

9.1 Recommendations

1. Capacity building and professional development

Strengthening the digital competencies of pre-service teachers requires a shift toward hands-on, practice-based training. Institutions should implement structured ICT training programs that focus on pedagogical integration, supported by mentorship from experienced educators. Regular ICT competency assessments and workshops should be conducted to ensure continuous growth, while peer-learning networks and digital platforms can offer sustained, collaborative learning opportunities beyond formal coursework.

2. Infrastructure and resource accessibility

Foundational to any ICT integration effort is the provision of reliable infrastructure. Priority should be given to expanding internet connectivity, especially in rural and underserved regions. Investment in digital tools, such as laptops, tablets, and interactive whiteboards alongside the development of smart classrooms and ICT resource centers will ensure that teacher training environments are equipped to support modern, technology-enhanced pedagogy.

3. Policy alignment and strategic partnerships

For sustainable ICT integration, policies must move beyond guidelines to actionable implementation. ICT training programs should be fully aligned with Rwanda's national education policies, with clear benchmarks and a robust monitoring and evaluation framework to track progress. To support long-term implementation, partnerships with government, private sector, NGOs, and educational institutions are essential. These collaborations can help mobilize funding, distribute resources equitably, and scale innovative practices across diverse educational contexts.

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Author contributions

The task distribution for the final manuscript development is as follows: IT and JP will work on the Introduction and Background; RM and OO will handle the Literature Review; OH and IN will develop the Methodology; EN and LM will write the Findings and Discussion; FM and NE will be responsible for the Conclusion and Recommendations; Proofreading and Final Editing will be done by JP and IT; and OH and NE will manage the Formatting and Reference Management.

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Data availability

Because of reasons of sensitivity and protection of anonymity, the data that support the findings of this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate:

This study received ethical approval for its general characteristics from the University of Rwanda College of Education, Research, and Innovation Ethics Committee (letter ref: 003/03/24). An individual ethical review was not required, as the study falls into a category exempt from such review. Studies qualify for general ethical approval if it can be confidently and easily assumed that participation will not cause any physical or mental harm or discomfort beyond everyday experiences and if the study relies on data that were fully anonymized at the source (e.g., through an anonymous online survey). The participants have signed the Consent to participate and publish the results from this study in accordance with the Declaration of Helsinki.

Consent for publication

All participants have provided their written consent for the publication of the data included in this manuscript.

Competing interests

The authors declare no competing interests.

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