CHAPTER SEVEN

The integration of ICT pedagogy: A panacea to mathematics teacher training in South African universities

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Abstract: Information and Communication Technology (ICT) pedagogy involves exposing pre-service teachers (PSTs) to the integration of ICT across the curriculum as a teaching and learning strategy. Research in university teacher training indicates that there is little to no instruction on ICT integration in the teacher training programmes of South African universities. While today's PSTs appear to be skilled ICT users, it is a miscon- - 105 -aption to assume that they have developed adequate skills outside their teacher training programmes. Therefore, universities need to capitalise on ICT pedagogy for mathematics PSTs by equipping them with essential technology tools for teaching. ICT integration into mathematics teaching and learning promotes collaboration, communication, and knowledge-sharing among learners. Although there is access to ICT tools at universities today, it is important to note that access is not synonymous with competency; hence, mathematics PSTs require skills to integrate these ICT tools into their teaching. Adopting a critical literature review, this chapter aims to analyse the approaches that can be used to teach pre-service mathematics teachers to integrate ICT into their instruction. This will be achieved by exploring the importance of exposing PSTs to ICT pedagogy, investigating the extent and ways in which technology is used in teacher-training institutions, understanding how these institutions prepare mathematics PSTs for the integration of ICT in their future classrooms, and exploring the approaches teacher educators can use to teach mathematics PSTs to integrate ICT in their teaching.

Keywords: ICT integration, ICT pedagogy, innovative technologies, mathematics teaching, pre-service teachers.

1. Introduction

ICT is an integral part of the teacher education system as it helps pre-service teachers meet the challenges of a digitalised educational environment. Over 80% of communication now occurs digitally, emphasising the need for ICT-based training (Morrison et al., 2023). Moreover, an emphasis on basic numeracy and critical thinking skills is essential for fostering problem-solving skill development and preparing learners for science and technology careers. Universities should realign with current educational needs to address the gaps in mathematics teacher education training, where equitable practical and technology-based methods are the centrepiece of teacher education. South Africa will adequately strengthen its pre-service mathematics teachers to effectively ignite and educate generations to come by cultivating an intersection of content and pedagogical skills.

Effective teacher training is fundamental to achieving excellence in mathematics education. Mainali (2021) postulates that teacher educators need to understand representations of their students' learning to teach mathematics most effectively. This is because proficiency in mathematics alone does not translate into effective teaching, as both require distinct skill sets. Teacher training for mathematics pre-service teachers aims to produce educators who enhance learner outcomes in the subject, a challenge compounded by historical and socio-political factors in South Africa (Khoza & Biyela, 2020; Morrison et al., 2023). This chapter critically examines approaches to ICT pedagogy in South African universities and pedagogical frameworks in mathematics teacher training, integrating historical and contemporary perspectives to propose forward-looking strategies.

The legacy of apartheid bequeathed deep inequalities in education, which framed teacher training policies and practices. Some initiatives and policy reforms, such as the Employment of Educators Act of 1998, aimed to homogenise teacher education across major disciplines toward greater equity and integration (Morrison et al., 2023). Furthermore, a dynamic training approach is required in South Africa, particularly due to the variety of educational backgrounds within the country. Alarming differences persist between theoretical training and classroom practices even after reforms. It has been noted that over 60% of secondary school graduates are taught only elementary mathematics, highlighting the critical need for strong teacher preparation (Morrison et al., 2023). In addition, rural and under-resourced schools must tackle the growing challenge of implementing innovative strategies that incorporate ICT in teaching.

1.1 Chapter outcomes

This chapter aims to expose teacher-educators to the importance of teaching mathematics to pre-service teachers (PSTs) how to use ICTs in their teaching. After reading the chapter, teacher-educators are expected to be able to:

- Recognise the significance of ICT pedagogy in teaching preservice teachers. Prepare PSTs for the integration of ICT in teaching mathematics.
- Be aware of the challenges and opportunities in integrating ICTs into mathematics instruction.
- Understand the pedagogical frameworks relevant to mathematics teacher training.
- Identify the approaches teacher-educators can employ to teach mathematics PSTs how to integrate ICTs into their instruction.

1.2 Clarification of concepts

- ICT pedagogy: A teaching approach that integrates ICT into the curriculum. It involves embracing technological advancements in teaching and learning to ensure growth, advancement, and sustainability in higher education (Adtani et al., 2023).

- Pre-service teacher: An individual who is undergoing training and education to become a teacher but has not yet begun teaching professionally. Abedi et al. (2024) indicate that PSTs are teachers in training.
- ICT integration: Mnisi et al. (2024) define ICT integration as the use of technology in teaching and learning, including computers, the internet, and communication networks, to enhance the quality of instruction, making it more accessible and cost-effective.
- Innovative educational technologies: New or improved products, processes, or services that utilise technology to solve problems or enhance existing practices, thereby facilitating teaching and learning (Chugh et al., 2023).

2. The Importance of Exposing PSTs to ICT Pedagogy

The role of ICT in the classroom is becoming increasingly important, as learners need to develop skills that will empower them in contemporary society, and because of the potential value of such technologies as tools for learning. The Minimum Requirements for Teacher Education Qualifications (MRTEQ) policy document stipulates that a teacher's ability to use ICT for innovation in teaching and learning is essential (DHET, 2015). One of the many reasons to expose pre-service teachers (PSTs) to ICT pedagogy is the need to equip them with the skills to contribute to and thrive in an information society, as well as to produce a technologically skilled and flexible workforce. Furthermore, as technology becomes more deeply embedded in teaching and learning, future educators must understand how to effectively integrate ICT tools and strategies into their practice. Jita and Dhliwayo (2024) indicate that ICT-integrated pedagogy enhances teaching and learning, increases engagement and motivation for PSTs, and promotes active and personalised learning. Schools are increasingly adopting digital platforms for communication, lesson delivery, and administrative tasks; therefore, PSTs must be comfortable navigating these systems to work effectively within these environments. This perspective is echoed by Ma et al. (2024), who indicate that as technology continues to evolve, teachers must be adaptable and flexible in their approach. Learning ICT pedagogy prepares PSTs to stay up-to-date with emerging technologies and apply them in creative ways. When PSTs are well-prepared to incorporate ICT into their teaching, they not only enhance their teaching effectiveness but are also equipped to empower their learners to become critical, engaged, and competent users of technology in a rapidly changing world. Integrating ICT pedagogy not only encourages PSTs to learn how to use technology for their professional development, but also teaches them how to apply these skills in their future classrooms (Jita & Sintema, 2022).

Preparing PSTs to use ICT in their future classrooms to facilitate a variety of learning styles has been a challenge for most teacher training institutions. Mncube and Olawale (2020) indicate that integrating ICT pedagogy at institutions of higher learning is fundamental to modernising higher education and equipping students with the tools and skills necessary for success in an increasingly digital world. By embracing technology in teaching, learning, assessment, and administration, universities can foster more engaging, inclusive, and personalised educational

experiences. Moreover, Wessels (2020) asserts that ICT pedagogy enables universities to remain adaptable in a rapidly changing educational landscape. Resonating with this view are Akour and Anelezi (2022), who assert that ICT pedagogy ensures that students graduate with the critical digital and collaborative skills they will need in their future classrooms. While some universities face the challenge of insufficient ICT infrastructure and equipment for their students, others encounter the problem of inadequate training and experience of teacher-educators in teaching with ICT, all of which hinder the effective incorporation of ICT into teachers' education (Kennedy, 2023).

Mathematics PSTs can benefit from ICT pedagogy by providing differentiated instruction to their learners through representation, engagement, and expression. Through various types of digital assessments, and in their future classrooms, PSTs can quickly gather formative data, allowing them to adjust their instruction based on learners' needs. Marbán and Sintema (2021) suggest that using software enables teachers to customise lessons for diverse learners, such as employing voice narration or visual aids for students with varying learning requirements. When mathematics PSTs are exposed to ICT pedagogy, they can utilise it to track learners' progress, identify areas of difficulty, and provide immediate support. Using technology like graphing tools, interactive visualisations, or problem-solving apps, PSTs can explore mathematical concepts and build their knowledge (Makamure & Jojo, 2021). This approach encourages inquiry-based learning, where they can hypothesise, experiment, and reflect, deepening their understanding of mathematical concepts. Sithole and Mbukanma (2024) further state that incorporating ICT pedagogy into the training of mathematics PSTs equips them with essential skills and strategies to enhance student engagement, foster deeper learning, and prepare their students for future academic and professional success. Additionally, ICT pedagogy supports PSTs' continuous professional growth in a rapidly evolving educational landscape. With the aid of relevant technologies, PSTs will be able to solve complex mathematical problems, think creatively and critically, communicate, and collaborate with others from diverse backgrounds. However, a key challenge for teacher educators is delivering learning experiences at university that allow PSTs to develop technological, pedagogical, and content knowledge skills and capacities.

3. The Current State of Mathematics Teacher Training in South Africa

Education is the cornerstone of social development and economic growth; as a result, improving mathematics teacher training is necessary. Researchers often cite that learners' mathematics achievement is directly correlated to mathematics teaching competency (Khoza & Biyela, 2020; Morrison et al., 2023). This context provides an opportunity for us, as teacher educators, to ensure that teacher education programmes adequately prepare prospective mathematics teachers to respond meaningfully to the various forms of learning they will encounter in South African classrooms.

Mathematics teacher training in South Africa is conducted across various universities and universities of technology, aligning with the General Education and Training (GET) and Further Education and Training (FET) curricula (Morrison et al., 2023). The GET programme culminates in the final degree, the Bachelor of Education (B.Ed.), which equips beginning teachers with foundational mathematics pedagogical skills for teaching in primary schools. However, many primary school teachers, even after four years of training, have insufficient exposure to ICT. This gap frequently results in fears about the use of technology in the learning of mathematics, which is often aggravated by historical teaching methods that discourage the use of ICT (Shava, 2022). This suggests that they may be passing on poor attitudes toward mathematics and technology to learners, which is an important consideration in existing training models.

The challenges faced by teacher training institutions are compounded by the diverse contexts of South African schools. Mojapelo and Durodolu (2022) argue that some schools, particularly in rural areas, are under-resourced and already at a disadvantage due to insufficient infrastructure necessary for ICT integration. This further marginalises school users in such contexts. Unless specific measures are taken to address the lack of access to quality mathematics education, the inequalities will persist (Azhari & Farji, 2022), undermining the overall purposes of the South African education system. In a different context, Xu and Ouyang (2022) indicate that integrating ICT into education may signal a transformative leap, particularly in mathematics education, creating reflective teaching and interactive environments for learners. ICT tools not only encourage active learner participation but also align with constructivist approaches, positioning learners as active participants in constructing their knowledge. Some methodologies, such as Problem-Based, Inquiry-Based, and Project-Based Learning, adopt technology as a means to achieve meaningful communication and high-level problem-solving skills.

Moreover, integrating ICT pedagogy can strengthen the link between theoretical knowledge and its applications in teacher education. When ICT is embedded in lesson planning, teachers can use this technology effectively by showing learners real-life examples that help them learn important mathematical concepts. Such an approach is not just engaging; it equips learners with the skills needed in a technology-led economy (Morrison et al., 2023; Xu & Ouyang, 2022). For the integration of ICT in mathematics teaching to be effective, teachers need to be knowledgeable in both pedagogy and technology. ICT-based teaching strategies are most relevant to the needs of knowledge adaptability and 21st-century skills, with a drive to provide learners with as much information as they seek (Mofokeng, 2022). Furthermore, these strategies foster the ability to identify necessary information by adopting critical thinking. These are all essential skills in preparing learners to thrive in an increasingly complex and interconnected world.

4. Challenges, Opportunities and Advantages of ICT Integration in Mathematics Teacher Training

4.1 Challenges

Marban and Sintema (2021) indicate that integrating ICT pedagogy into mathematics teacher training presents a transformative opportunity to enhance educational outcomes. ICT also provides pre-service teachers (PSTs) with access to a diversity of resources, innovative environments, and collaborative ventures that support personalised learning and digital literacy (Morrison et al., 2023; Xu & Ouyang, 2022). However, challenges still exist, particularly in contexts like South Africa, where infrastructure constraints and systemic barriers to implementation complicate the situation. This article discusses the key issues, approaches, and potential benefits of integrating ICT into mathematics teacher education programmes. For instance, in under-resourced schools and universities, unreliable internet connectivity, hardware, and software represent significant barriers (Aktaş & Özmen, 2020). The ICT experience of many PSTs in South Africa upon entering training programmes is minimal, and only once early experience has been established can more advanced pedagogical applications be introduced. Moreover, in-service teachers tend to overlook ICT integration, as they did not receive sufficient exposure during their training. This discrepancy is further compounded by inflexible curricula that address the immediate crises facing education rather than the technological innovations on the horizon. Additionally, limited professional development opportunities and the absence of a cohesive institutional support system have left many teachers underprepared to implement innovative practices.

4.2 Opportunities

Although ICT integration presents several challenges, it can provide numerous benefits and opportunities that positively impact mathematics teacher training. For instance, it encourages personalised learning and helps PSTs conveniently access tailored resources that meet their needs and address their learning preferences. Not only does this solidify their understanding of mathematical concepts, but it also enables them to deliver differentiated instruction to learners in their classrooms (Aktaş & Özmen, 2020; Morrison et al., 2023). ICT integration promotes collaboration among teachers, which is a critical element in developing communities of practice that support the exchange of ideas, resources, and best practices. Such networks offer a wealth of information that is particularly useful in mathematics education, where novel approaches to teaching and problem-solving are essential for learners' academic success. Finally, ICT integration into teaching and learning helps teachers engage students more effectively, promoting critical thinking, creativity, and problem-solving skills. Innovations using technologies like interactive simulations, virtual manipulatives, and data analysis software have been shown to make mathematics more accessible to learners.

4.3 Advantages

ICT integration offers significant advantages that can transform mathematics teacher training. First, it facilitates personalised learning, allowing preservice teachers to access tailored resources

that address their specific needs and learning styles. This approach not only improves their understanding of mathematical concepts but also enhances their ability to deliver differentiated instruction in the classroom (Aktaş & Özmen, 2020). ICT fosters collaboration among educators, creating communities of practice that encourage the sharing of ideas, resources, and best practices. These networks are particularly valuable in mathematics education, where innovative teaching strategies and problem-solving techniques are essential for student success. ICT equips teachers with the tools to engage students actively, promoting critical thinking, creativity, and problem-solving skills. By incorporating technologies such as interactive simulations, virtual manipulatives, and data analysis software, educators can make mathematics more accessible and engaging for learners. Hence, context-specific strategies are needed for successful ICT integration, as teachers and learners have different requirements (Morrison et al., 2023). For example, a South African university adapted its first-year mathematics pedagogy to illustrate data-led activities, such as spreadsheet-based data analysis and algorithm visualisation, which can supplement traditional arithmetic instruction. This adaptation enhanced learners' ability to compute while also developing logical reasoning and communication skills. An additional example is a project called Schools in Partnerships, which showcased the power of ICT to improve the quality of teacher professional growth and learner learning. This initiative empowered teachers to effectively integrate technology into their teaching practices by focusing on planning, execution, and ongoing support.

5. Pedagogical Frameworks in Mathematics Teacher Training

Reports based on recent research, conferences, and postgraduate studies offer crucial insights into the pedagogical frameworks informing mathematics teacher education at South African universities. These frameworks must align with the educational goals outlined in the post-1994 reforms while addressing the immediate developmental needs of South African schools, particularly those in underserved areas (Bakar et al., 2020; Morrison et al., 2023). Given that education is one of the most powerful functions for transforming society, reimagining teacher training in South Africa presents an opportunity with vast potential to enhance learning outcomes and address systemic challenges on their own terms.

Mathematics teacher training frameworks are based on three key pillars: sound theory, practical applications, and responsiveness to society's needs (Jaeger et al., 2023). The existing models need to transition from solely sociological or cognitive approaches to transformative perspectives that focus on developmental practices (Morrison et al., 2023). This transformation is especially important for schools in impoverished communities, where teachers face challenges such as poverty and the continuing fallout of the HIV/AIDS epidemic. Furthermore, frameworks need to embrace new pedagogy and a variety of learning environments. These frameworks can provide effective tools for teachers to navigate the complexities of modern classrooms by focusing on challenges specific to their communities.

Constructivist principles are foundational to modern mathematics teacher training. These methods encourage active learning, knowledge construction, and practical application, which, in turn, foster critical thinking and collaborative problem-solving (Morrison et al., 2023). Taken alone, constructivist frameworks demand a complete rethinking of how teachers interact with one another and with learners, promoting more interactive and learner-centred methodologies. Such methods move away from the traditional approach of rote memorisation and instead cultivate lifelong learning habits and the capacity to adapt to change.

While these frameworks have great potential, systemic obstacles impede their implementation. Resistance to change within educational institutions, insufficient pedagogical training for teachers, and budget constraints significantly affect the dissemination of innovative methodologies. Moreover, these limitations are compounded by a lack of partnerships with local organisations and the failure to provide adequate access to relevant contextual information, particularly in rural schools.

Some promising models, such as institutional-workplace collaboration (IWC) (Arinaitwe, 2021), have emerged, showcasing how collaboration can improve teacher training. The IWC refers to how teachers reflect on their co-development of questions concerning effective teaching and learning, such as through reflective practice workshops designed to empower teachers. To this end, regional stakeholders, including university representatives, Department of Basic Education (DBE) officials, and teacher unions, have come together to share best practices and build consensus on reform initiatives. Such practices demonstrate the value of collaboration and the need for customised initiatives that address specific institutional issues. They serve as a case study of how teacher training programmes can be rethought to meet local, unique concerns while also aligning with international education standards. Each of these collaborative efforts reinforces the idea that trust-based relationships are essential for advancing institutional reform. This process helps ensure that teacher training programmes remain both relevant and impactful by involving diverse stakeholders in the process.

6. Approaches Teacher-Educators Can Use to Teach Mathematics Preservice Teachers to Integrate ICTs in Their Teaching

6.1 Modelling

Teaching mathematics PSTs to integrate ICTs into their teaching requires a blend of theoretical knowledge, hands-on experience, and reflective practice. Teacher-educators can adopt several approaches to ensure that PSTs are well prepared to integrate ICTs effectively into their teaching practices. One approach is for teacher-educators to model ICT integration in their own teaching (Adnan et al., 2024). Dewa and Ndlovu (2022) argue that while teacher-educators possess knowledge of how to teach with digital technologies in their lecture rooms, they often do not model specialised mathematics teaching skills for their students. Therefore, through active demonstration, teacher-educators can showcase the use of ICT tools during their lessons. By

demonstrating how to integrate technology seamlessly into lessons, PSTs can observe the practical application of ICT tools, such as graphing software like GeoGebra, dynamic geometry tools, or online platforms such as Desmos and Wolfram Alpha. Teaching PSTs to integrate ICTs in their mathematics teaching involves equipping them with both technical skills and pedagogical strategies. Supporting this view, Stockless et al. (2022) argue that university curricula should take responsibility for equipping PSTs with both technical and pedagogical knowledge.

6.2 ICT-infused lesson planning

To support mathematics PSTs in integrating ICT into their teaching, Lim et al. (2011) indicate that each programme they are involved in, which includes curriculum, assessment, and practicum, should be ICT-infused. This involves teaching PSTs to design lesson plans that effectively integrate ICT. Key elements of lesson planning include aligning the use of technology with learning objectives, designing tasks that leverage technology to visualise or explore mathematical concepts, and incorporating interactive or formative assessment tools. PSTs can be introduced to real-world data sets that can be analysed using ICT tools. For example, they can use software like Excel or Google Sheets to create statistical models or solve real-world mathematical problems, demonstrating the relevance of mathematics in everyday life. By thoughtfully incorporating ICT tools, PSTs can enhance teaching and learning, creating engaging, interactive, and differentiated lessons that cater to the diverse needs of learners. Janssen et al. (2019) indicate that ICT can be aligned with lesson objectives and incorporated to support content delivery. Mathematics PSTs should be taught how to plan for differentiation of instruction in mathematics classrooms and leverage ICT tools to adjust teaching and learning to individual learner needs (van den Kieboom & Groleau, 2022).

6.3 Workshops for PSTs

The advent of the Fourth Industrial Revolution (4IR) necessitated a shift in the alignment of pedagogical activities worldwide. As van Wyk and Waghid (2023) indicate, South African pre-service teachers (PSTs) generally deem themselves unqualified and incompetent to teach in South African schools using ICT, particularly in mathematics. South African universities can provide workshops that introduce PSTs to a range of ICT tools suitable for the mathematics classroom. These workshops should focus on practical applications, such as creating interactive lessons, assessments, and visual aids using these tools. Although Pule and Raxangana (2024) indicate that, as a developing country, South African teachers face challenges in using mathematical software to enhance teaching and learning in schools, Nhlumayo (2024) asserts that most teachers were never guided on using ICT for teaching in their training programmes. Khoza and Biyela (2020) postulate that PSTs arrive at universities owning both technological hardware (smartphones and/or laptops) and software (Facebook, X, WhatsApp, Instagram, etc.). However, since ownership is not synonymous with ability, it is the responsibility of universities to introduce PSTs to mathematical ICT tools and simulations. These may include

innovative technologies such as GeoGebra, Desmos, Microsoft Excel, Google Classroom, Moodle, PhET Interactive Simulations, and Wolfram Alpha, which can model complex mathematical concepts and visualisations that might otherwise be difficult to explain. As part of ICT pedagogy, South African universities must include the basics of digital literacy and computational thinking in their teacher preparation programmes, thus helping PSTs to become proficient not only in using mathematical software but also in evaluating online resources.

7. Conclusion

To prepare mathematics PSTs for ICT-integrated pedagogy, South African universities must offer a curriculum that integrates ICT training with content and pedagogy, provides hands-on experience with technology, and emphasises the real-world application of ICT in mathematics classrooms. Integrating ICT pedagogy into mathematics teacher training is essential for modernising education and ensuring that PSTs are well-equipped to meet the evolving needs of their learners. This chapter argues that the integration of ICT pedagogy improves mathematical conceptual understanding, particularly for concepts that may be difficult to grasp, such as calculus, algebraic structures, or geometry. Moreover, it contends that the integration of ICT pedagogy prepares future mathematics teachers for the digital age. Furthermore, this chapter posits that ICT pedagogy also facilitates different forms of assessment for mathematics, such as online quizzes and digital portfolios. This can assist PSTs in easily tracking their learners' progress, identifying areas where learners are struggling, and adjusting their teaching accordingly. By fostering technical proficiency, pedagogical expertise, and awareness of the socio-economic context, universities can ensure that PSTs are well-prepared to teach mathematics using ICT effectively, enhancing student engagement and learning outcomes across South Africa's diverse educational settings.

Integrating ICT pedagogy into mathematics teacher training is vital for developing a more effective, engaging, and inclusive educational experience. Equipping PSTs with the skills to use technology effectively enhances their academic outcomes, promotes digital literacy, and prepares them for future challenges. Furthermore, it supports diverse learning styles, fosters collaboration, and offers tools that make mathematical concepts more accessible and engaging. Ultimately, the integration of ICT pedagogy empowers teachers and students, preparing them for the demands of the modern digital world.

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