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Innovative Teaching through Technology: Preparing Educators for ICT-Based Modelling and Simulation Integration

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Abstract: The integration of Information and Communication Technology (ICT) based modelling and simulation in education has the potential to transform teaching and learning by enhancing student engagement, conceptual understanding, and problem-solving skills. However, barriers such as inadequate teacher training, limited digital infrastructure, and policy misalignment hinder widespread adoption, particularly in South Africa's under-resourced educational institutions. This study examines teacher professional development programs, institutional strategies, and policy interventions aimed at equipping educators with the necessary digital competencies to integrate ICT tools into pedagogy effectively. Using a qualitative research approach, the study synthesizes secondary data from peer-reviewed journal articles, institutional reports, and academic databases. Findings indicate that while some educational institutions have successfully implemented ICT-based learning models, disparities in access, digital literacy, and institutional support persist. The study recommends structured, tiered teacher training programs, increased investment in ICT infrastructure, and stronger policy frameworks to ensure sustainable ICT integration. Addressing these challenges will be critical in bridging the digital divide and fostering a technology-driven education system that prepares students for the demands of the 21st century.

Keywords: ICT Integration, Modelling and Simulation, Teacher Professional Development, Digital Pedagogy, Educational Technology, Policy Implementation.

I. INTRODUCTION

"In today's Knowledge Society, conceiving education without ICT is unthinkable" (Almerich, Gargallo-Jaquotot & Suárez-Rodríguez, 2024, p. 1). Indeed, in the contemporary digital age, Information and Communication Technologies (ICTs) have emerged as essential tools in education, transforming traditional pedagogies and fostering innovative learning environments (Naicker, 2017). The integration of ICT in education is increasingly recognised as a crucial component of effective teaching and learning processes, particularly in the South African context, where digital transformation is integral to bridging educational inequalities and enhancing teaching methodologies (Graham, Kruger & van Ryneveld, 2024). The South African education system has seen significant investment in ICT infrastructure and teacher training to facilitate its integration into classroom practices. However, despite these efforts, research indicates that ICT adoption in schools remains inconsistent, with challenges such as inadequate teacher training, limited technological resources, and resistance to pedagogical change (Naicker, 2017, p. 4). According to Valverde-Berrocoso et al. (2021), teachers have been forced to implement emergency remote education without sufficient preparation, highlighting existing gaps in ICT competencies. The rapid advancement of Information and Communication Technology (ICT) has transformed educational systems worldwide, with significant implications for teaching and learning practices. In South Africa, the adoption of ICT in education is seen as a crucial step towards modernising pedagogical approaches and addressing persistent educational challenges, such as resource shortages and disparities between urban and rural schools (Graham, Kruger & van Ryneveld, 2024)
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The South African government has recognised the transformative potential of ICT, as reflected in policies such as the White Paper on e-Education (Department of Education, 2004), which envisions all learners and educators having access to digital technologies to improve teaching and learning. However, despite national efforts to integrate ICT into education, its implementation remains uneven. While some schools particularly those in urban areas have successfully incorporated digital tools into the curriculum, many institutions, especially in rural and underprivileged communities, struggle with infrastructural constraints, lack of digital literacy, and inadequate training for teachers (Naicker, 2017, p. 4). The assumption underlying this paper is that the integration of ICT-based modelling and simulation can enhance the quality of education by fostering interactive and experiential learning. Modelling and simulation tools offer students opportunities to engage with complex concepts through visualisation and practical application, which are particularly valuable in resource-constrained environments (Rani et al., 2020). However, successful ICT integration depends not only on access to technology but also on the preparedness and willingness of educators to incorporate digital tools into their pedagogical practices (Schlebusch, Bhebhe & Schlebusch, 2024).

Given these challenges, this study seeks to examine how ICT-based modelling and simulation can be effectively integrated into South African education. The study adopts a qualitative research approach, relying on secondary data from journal articles, reports, and academic databases, to analyze the barriers and enablers of ICT adoption. Specifically, this research aims to answer the following key questions:

1. How can ICT-based modelling and simulation enhance teaching and learning in South African education?
2. What are the key challenges faced by educators in integrating ICT-based modelling and simulation into their teaching practices?
3. What role do teacher training and professional development play in supporting the effective use of ICT-based modelling and simulation in education?
4. What policy and institutional strategies can be implemented to support the widespread adoption of ICT-based modelling and simulation in South African education?

This study contributes to the growing body of knowledge on digital pedagogy and teacher professional development, offering insights into how educators can be empowered to effectively use ICT-based tools. The findings will provide actionable recommendations for policymakers, institutions, and educators to bridge the digital divide and improve learning outcomes through ICT-driven teaching strategies.

II. METHODOLOGY

This study adopts a qualitative research approach to explore the integration of ICT-based modelling and simulation in teaching practices. The research relies on secondary data sources, including peer-reviewed journal articles, institutional reports, and academic databases such as Google Scholar, Scopus, and Web of Science. Thematic analysis was employed to categorise and interpret findings, ensuring a comprehensive understanding of the barriers and enablers of ICT integration. The study will synthesise existing research, this study aims to provide insights into effective strategies for equipping educators with the necessary digital competencies to enhance teaching and learning outcomes.

Technological Pedagogical Content Knowledge

The Technological Pedagogical Content Knowledge (TPACK) framework (Mishra & Koehler, 2006) serves as a theoretical foundation for understanding how educators integrate technology into their teaching practices by balancing content knowledge, pedagogical strategies, and technological tools. The framework extends Shulman's (1986) concept of Pedagogical Content Knowledge (PCK) by incorporating Technological Knowledge (TK), emphasising that effective teaching with technology requires more than just familiarity with digital tools, it demands an intricate interplay of subject knowledge, instructional methods, and the affordances of technology. This study applies TPACK to analyse how teachers incorporate ICT-based modelling and simulation into their pedagogy, highlighting the challenges and opportunities that arise from such integration. Research indicates that teachers often struggle with the Technological Pedagogical Knowledge (TPK) component, which involves understanding how different technological tools transform teaching strategies rather than merely supplementing traditional methods (Koehler & Mishra, 2009).

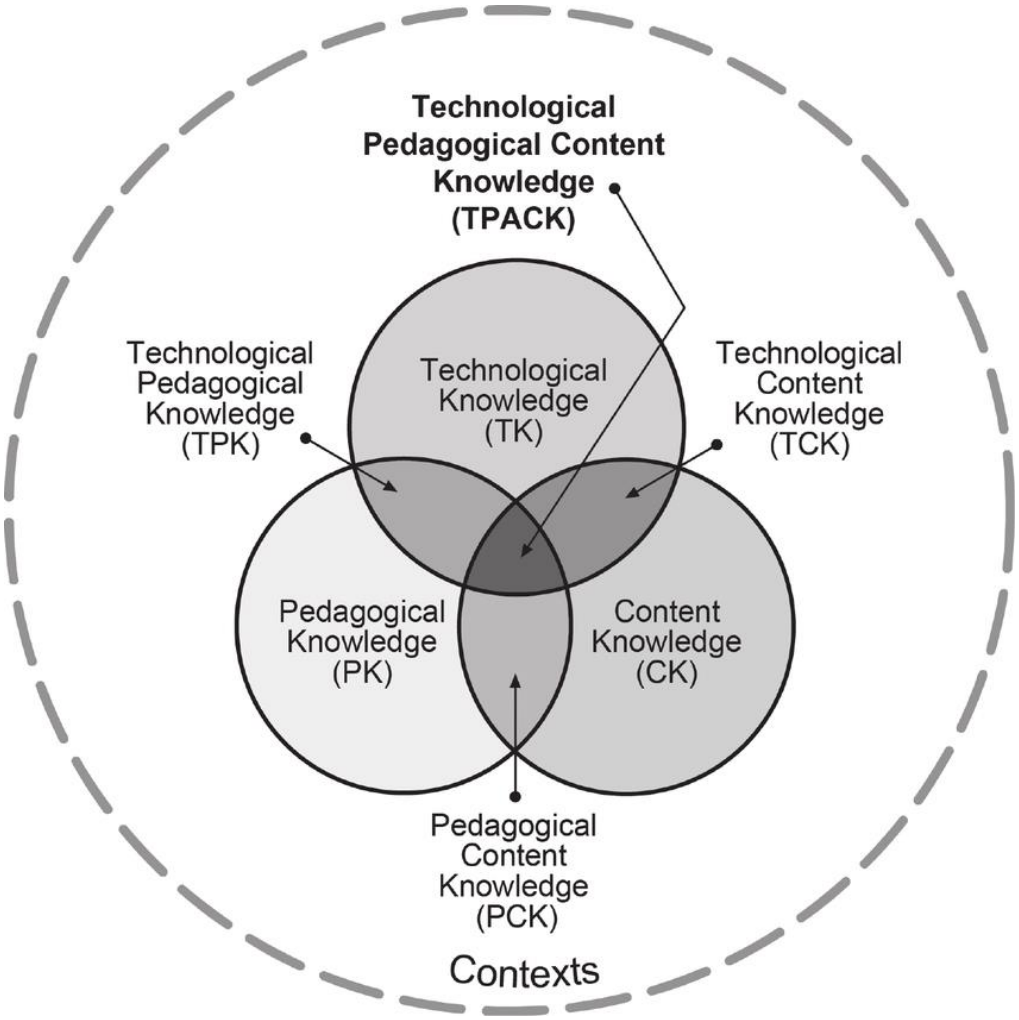

Figure 1: Technological Pedagogical Content Knowledge (TPACK) framework *(Reproduced by permission of the publisher tpack.org)*

The successful implementation of ICT in education is highly dependent on the context in which technology is introduced, as evidenced by studies conducted in South Africa and Ghana. Baako and Abroampa (2024) emphasise that factors such as limited infrastructure, inadequate teacher training, and lack of institutional support significantly impact teachers' ability to develop TPACK in underprivileged schools. For example, teachers who lack professional development opportunities often exhibit a low level of Technological Content Knowledge (TCK), meaning they are unfamiliar with how ICT-based simulations can enhance subject-specific teaching (Schmidt et al., 2009). This issue is compounded by disparities in access to digital resources, with rural schools facing more barriers than urban institutions. However, research suggests that when teachers receive targeted training and ongoing support, they develop a deeper understanding of how technology can be used not just to deliver content but to transform learning experiences, making subjects more interactive and engaging (Koehler et al., 2013).

The TPACK framework is particularly relevant for this study as it provides a structured approach to analysing both the barriers and enablers of ICT-based modelling and simulation adoption in education. Therefore, identifying gaps in teacher preparation and professional development, this research contributes to strategies for equipping educators with the necessary skills to integrate ICT effectively into their instructional practices. The framework underscores the need for professional development programs that do not treat technology as an isolated skill but rather as an integrated component of pedagogy and subject expertise. This holistic view of technology integration highlights the importance of a supportive learning environment, continuous mentorship, and adaptive teaching strategies that align with technological advancements. Ultimately, TPACK allows for a comprehensive

understanding of how teachers can be trained to use ICT-based modelling and simulation effectively, ensuring that technology enhances pedagogy rather than serving as a mere add-on in the classroom (Mishra & Koehler, 2006).

ICT Adoption in South African Schools and Higher Education Institutions

Information and Communication Technology (ICT) adoption has grown significantly in South African schools and higher education institutions, driven by policies like the e-Education White Paper and the National Development Plan (Department of Basic Education, 2004; National Planning Commission, 2012). The integration of ICT into the curriculum is intended to enhance teaching and learning outcomes, promote digital literacy, and address educational disparities. Despite these ambitions, progress in adoption has been uneven, with private institutions and urban schools typically advancing more rapidly than their rural counterparts (Isaacs, 2007). In schools, ICT adoption primarily revolves around computer-assisted learning, access to digital textbooks, and the integration of online platforms for homework and assessments (Makoe, 2010). Higher education institutions have embraced ICT through Learning Management Systems (LMS), blended learning, and virtual learning environments (Czerniewicz & Brown, 2014). Universities have further expanded their digital ecosystems with research databases, online libraries, and collaborative digital spaces. However, disparities remain in access, usage, and outcomes. Institutions in rural areas often face challenges related to infrastructure, internet connectivity, and the availability of devices (Van Deursen & Van Dijk, 2019). Urban institutions, on the other hand, benefit from partnerships with technology providers and better funding, allowing them to deploy advanced digital tools.

Artificial Intelligence and Simulated Learning at a Higher Education Institution in South Africa

The integration of Artificial Intelligence (AI) and simulated learning within higher education institutions in South Africa is increasingly gaining attention as a transformative force in teaching and learning. AI-powered technologies, including adaptive learning systems, intelligent tutoring, and automated assessment tools, offer unprecedented opportunities to enhance student engagement and personalise learning experiences (Ghavifekr et al., 2014). Simulated learning, which leverages AI to create interactive virtual environments, enables students to practice skills in real-time, reducing the dependency on physical resources while providing a more flexible and immersive learning experience (Darrah et al., 2014). These advancements are particularly beneficial in resource-constrained environments, where institutions face challenges related to funding, infrastructure, and access to quality learning materials (Rani, Singh, & Babu, 2020).

South African higher education institutions have recognised the potential of AI-driven simulated learning to bridge gaps in access to quality education. For example, universities are incorporating AI into their Learning Management Systems (LMS) to facilitate data-driven insights into student performance, helping educators tailor instruction to individual needs (Czerniewicz & Brown, 2014). Moreover, simulation tools in disciplines such as medicine, engineering, and business studies allow students to gain hands-on experience without the limitations of physical labs or equipment (Finkelstein et al., 2005). These tools provide cost-effective alternatives to traditional learning models, enabling students to engage in problem-solving and experiential learning that enhances their critical thinking skills (Bai & Wang, 2016). However, while AI and simulations present significant advantages, their adoption has been inconsistent across institutions due to disparities in digital infrastructure and faculty training (Naicker, 2017).

Despite the promise of AI and simulated learning, barriers to their widespread implementation persist. One of the most pressing issues is the digital divide, which continues to hinder equitable access to technology-enhanced education (Van Deursen & Van Dijk, 2019). Many universities, particularly those in rural areas, struggle with inadequate internet connectivity, limited access to digital devices, and insufficient funding to sustain AI-driven initiatives (Graham, Kruger, & Van Ryneveld, 2024). Additionally, faculty resistance to adopting AI-based teaching methods has been observed, primarily due to a lack of professional development and technical support (Schlebusch, Bhebhe, & Schlebusch, 2024). Addressing these challenges requires comprehensive institutional policies that prioritise digital literacy training for educators, investment in AI infrastructure, and collaborations with technology providers to develop localised and context-relevant AI applications in education (Majumdar, 2024).

Looking ahead, the successful integration of AI and simulated learning in South African higher education institutions will depend on a multifaceted approach that includes policy support, investment in technology, and capacity-building initiatives for educators (Isaacs, 2007). Research suggests that AI-powered adaptive learning and simulations can significantly improve student learning outcomes when implemented effectively, particularly in disciplines requiring experiential learning (Valverde-Berrocoso et al., 2021). By leveraging AI to create dynamic, student-centered learning environments, higher education institutions can drive innovation and enhance the overall quality of education in South Africa. However, to maximise the impact of AI in education, stakeholders must address

infrastructural challenges, foster digital equity, and ensure that educators are equipped with the necessary skills to integrate AI tools effectively into their teaching practices (Department of Basic Education, 2015).

Teacher Readiness and Professional Development Gaps in Artificial Intelligence and Simulated Learning

While AI-driven tools have the potential to enhance teaching practices and improve student outcomes, many educators remain unprepared to effectively integrate these technologies into their pedagogy (Meylani, 2024). The lack of comprehensive training programs, infrastructural challenges, and the digital divide contribute to these readiness gaps, particularly in developing regions such as South Africa. Without proper training and institutional support, educators struggle to harness AI's full potential in their classrooms (Purnama et al., 2025). A major challenge in teacher readiness is the limited access to AI literacy programs that focus on both theoretical and practical applications. Many teachers lack sufficient technological content knowledge (TCK) and the necessary pedagogical strategies to integrate AI-based learning tools into their teaching practices (Yim & Wegerif, 2024). This gap is exacerbated by a lack of institutional investment in AI-driven professional development, leaving educators with outdated skills in an increasingly digital learning environment. According to Tan et al. (2024), only 35% of research studies on AI in education focus on teacher training and professional development, underscoring a critical imbalance in AI integration efforts. Teachers require structured training programs that provide hands-on experience with AI-powered simulations, intelligent tutoring systems, and adaptive learning platforms to build confidence and expertise in using AI tools effectively (al-Zyoud, 2020).

Another barrier to teacher preparedness is the infrastructural disparity between urban and rural institutions. Research indicates that educators in urban areas have greater access to AI training materials and advanced technologies, whereas rural teachers often lack the necessary digital infrastructure (Purnama et al., 2025). This digital divide limits the ability of rural educators to experiment with AI-enhanced learning environments, creating inequities in student learning experiences. The study by the U.S. Department of Education (2023) emphasises that AI-driven teacher training must be contextually relevant and tailored to different learning environments to bridge this gap. Furthermore, teacher resistance to AI adoption stems from concerns about workload increases, data privacy, and the ethical implications of AI in education. According to literature, Many educators express scepticism about AI's role in decision-making, fearing that it may undermine their professional judgment and teaching autonomy (Meylani, 2024).

Addressing these professional development gaps requires a multi-faceted approach. First, educational institutions must invest in AI-focused training programs that incorporate real-world applications of AI in teaching, including simulations, gamified learning experiences, and AI-driven analytics. To address ICT integration challenges, South Africa's Department of Education should revise existing policies to mandate structured ICT teacher training at all levels of education. Specifically, introducing regional digital training hubs could allow teachers from under-resourced areas to gain hands-on experience. Furthermore, public-private partnerships should be expanded, enabling tech companies to provide cost-effective digital devices and software solutions tailored to South African schools. Second, governments and policymakers must develop national strategies for AI literacy that include digital equity measures to support under-resourced schools (Tan et al., 2024). Lastly, professional development initiatives should include continuous mentorship programs, allowing teachers to receive ongoing support as they integrate AI technologies into their pedagogy. As such, by equipping teachers with the necessary digital competencies and pedagogical strategies, AI and simulated learning can be effectively harnessed to transform education and improve learning outcomes for students across diverse educational settings.

Optimising Learning through Modelling and Simulation Tools in Resource-Constrained Educational Environments

Modelling and simulation tools are invaluable in resource-constrained educational environments, offering cost-effective and scalable teaching solutions (Rani et al., 2020). They provide opportunities for experiential learning by replicating real-world scenarios and complex systems within a virtual space. For example, in science education, virtual labs can simulate chemical experiments without the need for physical materials, reducing costs and risks (Darrah et al., 2014). The adoption of modelling and simulation tools in education has emerged as a powerful solution for overcoming the challenges faced by resource-constrained institutions. These tools provide an effective means for students to engage with complex concepts through interactive, visual, and experiential learning approaches (Mwansa, Ngandu, & Dasi, 2024). In environments where access to physical laboratories and traditional educational resources is limited, simulation-based learning bridges the gap by offering virtual, cost-effective, and scalable alternatives. Through simulations, students gain hands-on experience in disciplines such as engineering, medicine, and computer science, reinforcing theoretical knowledge with practical application (Brigas, 2019).

One of the key benefits of simulation tools is their ability to enhance learning outcomes in technical fields, particularly in higher education settings where access to real-world equipment is expensive or logistically challenging. Studies have shown that network simulation tools like Cisco Packet Tracer enable students to develop practical networking skills without requiring access to costly physical infrastructure (Mwansa et al., 2024). Similarly, in medical education, simulation-based learning has been widely adopted to train nursing students, allowing them to practice patient care scenarios in a controlled, risk-free environment (Moabi & Mtshali, 2022). These virtual learning environments also foster critical thinking and problem-solving skills by allowing students to test different approaches, analyse outcomes, and refine their understanding in real time (Brigas, 2019). Despite their potential, the integration of simulation and modelling tools in resource-constrained settings faces several barriers. Key challenges include limited access to digital infrastructure, inadequate teacher training, and resistance to adopting new teaching methodologies (Pather & Ragolane, 2024). In many under-resourced institutions, unreliable internet connectivity and a shortage of up-to-date computer systems hinder the widespread implementation of simulation-based learning. Additionally, educators often lack the necessary training to incorporate modelling tools effectively into their teaching practices. A study by Brigas (2019) highlighted that while simulation enhances engagement and comprehension, many teachers struggle with the complexity of these tools and require targeted professional development to utilise them optimally.

To maximise the benefits of modelling and simulation in resource-limited environments, institutions must prioritise investments in digital infrastructure and faculty training. Policies that support the integration of ICT-based modeling tools should be developed, ensuring equitable access to digital learning resources (Pather & Ragolane, 2024). Moreover, collaboration with technology providers can facilitate the deployment of cost-effective simulation platforms tailored to the needs of underprivileged institutions. As demonstrated in the case of South African higher education institutions, the adoption of AI-driven and simulation-based learning tools has the potential to revolutionise education by making learning more interactive, accessible, and inclusive (Mwansa et al., 2024). By addressing these challenges, simulation-based learning can become a transformative force in education, empowering students and educators to engage with content dynamically and effectively. Key benefits of using modelling and simulation tools include:

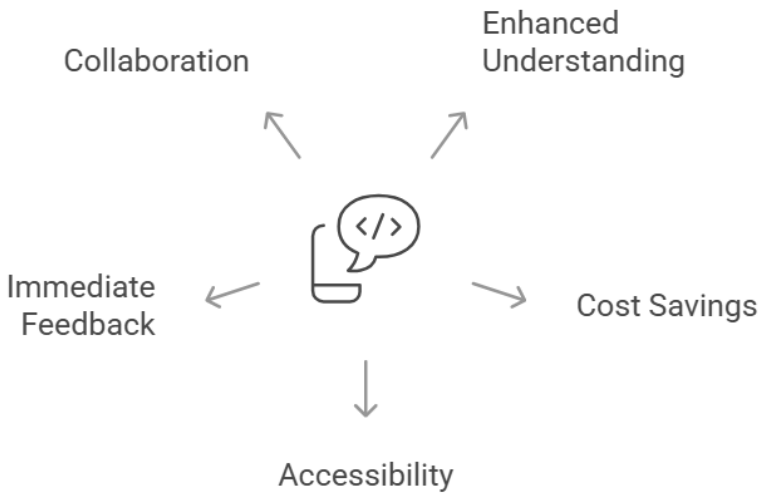

Figure 1: Benefits of modelling and simulation
Source: Authors

- **Enhanced Conceptual Understanding:** Complex concepts can be demonstrated visually and interactively, making them easier for students to grasp (Bai & Wang, 2016).
- **Cost Savings:** Institutions can save on expensive equipment, materials, and physical resources (Finkelstein et al., 2005).
- **Accessibility:** Remote and under-resourced schools can access quality educational experiences through digital means (Cavanaugh et al., 2004).
- **Immediate Feedback:** Interactive simulations often provide real-time feedback, allowing students to learn from their mistakes and adjust accordingly (Warren et al., 2009).
- **Collaboration:** Digital simulations support group work and collaborative problem-solving activities, fostering teamwork and communication (Johnson & Johnson, 2014).

In South Africa, these tools have been particularly beneficial in subjects like science, engineering, and business simulations, where practical exposure is critical. The deployment of such tools helps bridge gaps in traditional resource availability, levelling the playing field for disadvantaged students (Isaacs, 2007).

Challenges and Barriers to Implementation

The integration of ICT in education is widely recognised as a transformative force, yet its adoption remains hindered by multiple barriers, particularly in South Africa. The challenges stem from systemic inequalities, financial limitations, and insufficient institutional support. To be more precise, South Africa faces unique challenges in the integration of ICT into education, stemming largely from historical inequalities and socio-economic disparities. Key challenges include:

Digital Divide

As Francis Pebolo et al. (2024) mentions "the fulfilment of technology in education aligns with the United Nation's Sustainable Development Goal (SDG) 4, ensuring inclusive and equitable education and promoting lifelong learning opportunities, despite the absence of a specific target for educational technology in the SDG." However, this has not been realised in most of the institutions as the digital divide continues to be a major impediment to ICT integration in South Africa. Many schools, particularly in rural and underserved communities, lack access to basic infrastructure such as computers, reliable internet connectivity, and even electricity (Van Deursen & Van Dijk, 2019). This disparity exacerbates educational inequalities, as urban and well-funded private institutions have significantly better access to digital resources, widening the performance gap (Graham, Kruger, & Van Ryneveld, 2024). A study on ICT readiness in Gauteng schools found that many students lacked access to personal computing devices and reliable internet, making it difficult for teachers to integrate digital tools into their lessons effectively (Naicker, 2017).

Unequal Access to Resources

The unequal distribution of technological resources across South African schools continues to hinder ICT-based teaching. While wealthier schools and institutions can afford advanced technology and ongoing training, many disadvantaged schools struggle with outdated or insufficient resources (Makoe, 2010). A large-scale study using TIMSS data found that more than 50% of students attend schools that lack computers or tablets, and in nearly 90% of schools, these devices are not available for classroom use (Graham et al., 2024). Additionally, many teachers, particularly in public schools, do not receive sufficient access to digital pedagogical tools that would allow them to integrate ICT into their teaching practices effectively (Majumdar, 2024).

Training Deficits and Teacher Preparedness

Teacher preparedness remains a critical challenge in ICT integration. Studies have consistently shown that many teachers lack the necessary digital skills and pedagogical training to implement ICT-based teaching methods effectively (Mentz & Mentz, 2003). The South African White Paper on e-Education (Department of Education, 2004) aimed for all teachers to be ICT-capable by 2013, yet a more recent study revealed that a significant number of educators are still not adequately trained to integrate ICT into their pedagogy (Naicker, 2017). Similarly, a study by Schlebusch et al. (2024) found that lecturers at two Southern African universities initially struggled with digital literacy, requiring extensive training and ongoing support to transition from traditional face-to-face methods to technology-enhanced learning. Additionally, Valverde-Berrocoso et al. (2021) highlight that the sudden shift to emergency remote education during the COVID-19 pandemic exposed the lack of preparedness among teachers, as many were forced to implement digital teaching strategies without prior training. This underscores the need for structured, long-term professional development initiatives rather than short-term workshops that often fail to address practical classroom challenges.

High Costs of Implementation

The financial burden associated with ICT adoption poses another significant barrier. Initial investments in digital infrastructure, maintenance, software licensing, and digital content creation place financial strain on public schools, particularly those with limited budgets (Isaacs, 2007). In Kenya, for instance, Kisirkoi (2015) noted that while the government initiated projects to integrate ICT into education, inadequate financial resources hindered their sustainability. A similar trend is observed in South Africa, where financial constraints prevent many schools from maintaining and upgrading their digital resources over time. Moreover, Graham et al. (2024) found that despite significant investments in ICT infrastructure, its impact on student performance remains minimal, suggesting that financial investments alone are insufficient. Effective ICT integration requires a holistic approach that includes teacher training, pedagogical support, and policy-driven strategies.

Language and Cultural Barriers

Another overlooked challenge in ICT integration is the relevance of digital content to South Africa's multilingual and diverse educational landscape. Many educational technologies and digital learning platforms are designed for global markets, often failing to accommodate South Africa's linguistic and cultural diversity (Ratheeswari, 2018). The lack of local language support in digital learning resources makes it difficult for non-English-speaking students to engage with ICT-based learning materials, particularly in rural schools.Furthermore, research by Kisirkoi (2015) emphasises the importance of culturally relevant digital tools, noting that the lack of localised content limits the effectiveness of ICT in enhancing learning outcomes. Addressing this issue requires investment in localised digital content development and the integration of indigenous knowledge into digital education platforms.

III. DISCUSSION, CONCLUSION AND RECOMMENDATIONS

The integration of Artificial Intelligence (AI) and simulation-based learning in South African higher education institutions presents both opportunities and challenges. AI-powered tools enhance personalised learning, adaptive assessments, and interactive teaching methods, while simulation-based learning provides cost-effective, hands-on experiences for students, particularly in technical and scientific disciplines (Brigas, 2019). However, despite the potential benefits, the implementation of AI and simulation tools remains inconsistent due to disparities in digital infrastructure, teacher readiness, and institutional support (Yim & Wegerif, 2024). A major challenge is the lack of teacher preparedness and digital literacy. Literature mentions that many educators lack training in AI-driven pedagogies, preventing them from fully leveraging technology in the classroom. Additionally, the digital divide continues to limit equitable access to AI-enhanced education, particularly in under-resourced communities where internet connectivity and access to digital devices are inadequate (Van Deursen & Van Dijk, 2019). Research shows that teacher training must move beyond one-time workshops to long-term, structured programs. A three-tiered ICT training model could be implemented:

- Beginner Level: Basic digital literacy and introduction to ICT tools.
- Intermediate Level: Training on integrating AI, simulations, and modelling into subject-specific teaching.
- Advanced Level: Mastery-level courses on educational technology leadership, preparing teachers to train others.

Successful ICT integration requires that teachers not only learn new technologies but also understand how to embed them into pedagogical strategies. Schools must therefore prioritize ICT mentorship programs where experienced teachers support new adopters. Moreover, institutional policies and financial constraints further hinder AI and simulation adoption. While universities and government-led initiatives aim to integrate AI into education, sustainability issues remain a concern. Short-term programs often lack mentorship networks and follow-up support, leaving educators without the necessary tools to continuously adapt to digital advancements (Czerniewicz & Brown, 2014). Furthermore, language and cultural barriers prevent the effective use of AI tools in diverse learning environments, emphasising the need for customised, localised digital content (Ratheeswari, 2018). This study highlights the transformative potential of AI and simulation-based learning in South African higher education institutions while acknowledging the significant challenges that hinder their full-scale adoption. AI and simulation technologies bridge gaps in traditional learning methods, allowing students to engage with complex concepts through interactive and immersive experiences. However, teacher training deficiencies, limited digital infrastructure, and sustainability concerns remain barriers to effective implementation.

Despite various initiatives promoting ICT integration in education, rural schools continue to face limited access to AI-enhanced learning tools due to infrastructure constraints (Van Deursen & Van Dijk, 2019). Moreover, a lack of structured follow-up training and mentorship prevents educators from effectively incorporating AI and simulation into their teaching practices (Czerniewicz & Brown, 2014). Without adequate policy support, funding,

and tailored professional development programs, the integration of AI into education will remain fragmented and inaccessible to many students and educators. while AI and simulation-based learning have the potential to revolutionise education, their success depends on strategic investments in infrastructure, teacher capacity-building, and sustainable policy frameworks. Bridging the digital divide and ensuring equitable access to AI-driven education will be crucial for fostering inclusive, high-quality learning experiences that prepare students for 21st-century challenges.

This study demonstrates that ICT-based modelling and simulation have the potential to revolutionize teaching and learning in South Africa, yet widespread adoption remains hindered by teacher readiness gaps, financial constraints, and infrastructure disparities. To overcome these challenges:

- Teacher training programs must be standardized and continuous to ensure sustained professional development.
- Infrastructure investments should prioritize underserved schools, reducing the digital divide.
- Policy reforms should focus on integrating AI and digital tools into the national curriculum, ensuring ICT literacy for both educators and learners.

Future research should explore longitudinal studies on the effectiveness of ICT training programs and develop context-specific digital learning solutions for diverse South African classrooms. Without decisive action, the digital divide will continue to widen, limiting the potential of South African education in the digital era.

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