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Sustainability-aligned digital risks in South African higher education: a systematic review (2019–2025)

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This paper systematically reviews the intersection of digital transformation (DT) and sustainability within South African higher education institutions (SA HEIs) from 2019 to 2025. Drawing on global and local literature, the objective of the paper is to synthesise evidence on how SA HEIs navigate the dual imperatives of technological innovation and sustainable development. The paper sought to answer the *What sustainable digital risks have emerged for SA HEIs, between 2019 and 2025*? research question. Using the PRISMA approach and SPIDER framework, 40 peer-reviewed papers were analysed to identify emerging patterns, risks, and strategic gaps. The risks include deepening digital divides, infrastructural deficits, faculty capacity gaps, ethical concerns about data governance, and policy misalignment. These risks are interconnected: inadequate infrastructure hinders the development of digital literacy, with fragmented policies resulting in unsustainable investments and dependence on external suppliers. DT initiatives risk reinforcing educational stratification and undermining SDG 4 objectives, unless equity-driven strategies are embedded. This paper highlights the need for context-sensitive, equity-driven strategies that align digitalisation with long-term sustainability goals. The paper contributes to the discourse on inclusive and resilient higher education in developing contexts by offering insights for policy development, institutional planning, and future research.

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digital divide, digital transformation, higher education, South Africa, sustainability, systematic review

1 Introduction

Drawing on global and local literature, the paper examines how South African Higher Education Institutions (SA HEIs) balance the dual imperatives of technological innovation and sustainability. The systematic review, between January 2019 and September 2025, aims to synthesise and critically evaluate the academic and policy literature on sustainable digital risks within SA HEIs. The paper maps emerging patterns and assesses their implications for institutional sustainability. This study provides the first systematic synthesis of sustainability-aligned digital risks in South African higher education institutions. While existing reviews focus predominantly on the benefits of digital transformation (DT), this review foregrounds systemic risks that undermine long-term sustainability, equity, and institutional resilience. The study

advances the literature by integrating socio-technical, governance, and capacity-related risk dimensions within a developing-country's higher education context, offering evidence-based insights to inform policy and institutional strategy.

1.1 Digital transformation and sustainability in higher education

The intersection of DT and sustainability has redefined the global strategic landscape of higher education. Higher education institutions are increasingly being positioned as catalysts for technological innovation, environmental stewardship, and social equity (Andrade and Gonçalo, 2021). Digital transformation in HE is not merely a technological upgrade but a systemic shift influencing institutional operations, governance, and pedagogy (Elia et al., 2024).

The global landscape of HE is undergoing a profound transformation driven by the convergence of digitalisation and the urgent need for sustainability (Abad-Segura et al., 2020). This dual challenge, framed within the Fourth Industrial Revolution (4IR) and the United Nations Sustainable Development Goals (SDGs), necessitates a re-thinking of institutional strategy, governance, and operations (Clark et al., 2022). Although DT offers unprecedented opportunities for efficiency, access, and innovation, it simultaneously introduces new risks related to technological use, data security, and the potential to exacerbate existing socio-economic inequalities. In systematically reviewing the academic literature, this paper seeks to outline the strategic landscape, identify best practices, and highlight critical areas where DT enhances or compromises the long-term sustainability and equitable development of SA HEIs.

The integration of artificial intelligence (AI), big data analytics (BDA), blockchain, and immersive technologies such as virtual and augmented reality (VR/AR) has reshaped the delivery of teaching, learning, and administration in HEIs worldwide (Naidoo et al., 2024; Yang and Wu, 2024). Although DT improves efficiency, access, and innovation, it also exposes institutions to risks. In this regard, sustainability serves as both a guiding principle and a corrective framework, ensuring that digitalisation supports long-term social, economic, and environmental goals (Filho et al., 2023). The dual pursuit of digital advancement and sustainability, thus, constitutes a defining feature of HE in the 4IR.

1.2 The South African higher education context

In South Africa, the path of DT and sustainability is shaped by structural inequities embedded in the socio-economic landscape after apartheid (Cloete and Ndlovu, 2023). South African HEIs occupy a paradoxical position: they benefit from global technological advancements while being disproportionately affected by digital disparities. The coronavirus pandemic (COVID-19) underscored this reality, accelerating the adoption of hybrid and online learning models while exposing severe gaps in infrastructure, affordability, and digital literacy (Czerniewicz and Hodgkinson-Williams, 2005; Das, 2024).

Whereas well-resourced urban HEIs could rapidly pivot to digital teaching, rural and historically disadvantaged HEIs struggle to provide reliable connectivity, devices, and staff training (Nkambule and Ngubane, 2023). Consequently, the sustainability of DT initiatives in SA depends not only on technology integration but also on robust governance, inclusive policy frameworks, and capacity development.

The push towards sustainability-aligned digitalisation is reflected in national policy agendas such as the National Development Plan (NDP) 2030 and the Department of Higher Education and Training's digital strategy (Madon and Masiero, 2025; Siddiqi et al., 2020). South African HEIs have begun to incorporate sustainability principles into curricula, aligning research with the SDGs, and forming partnerships with industry to advance green innovation (Genga and Babalola, 2025). Nevertheless, implementation remains inconsistent. Weak policy coordination, bureaucratic inertia, and limited funding constrain progress, particularly in rural HEIs (Mahlangu and Mtshali, 2024).

1.3 Sustainable digital transformation risks

Digital transformation offers considerable opportunities to promote sustainability in education. Economically, digitalisation improves institutional efficiency, enables data-driven governance, and expands remote and rural access to education (Ayodele et al., 2025; Mohammadian et al., 2021). Socially, it improves inclusivity through flexible learning pathways, supports digital literacy, and fosters collaboration and workforce readiness for the 4IR (Beauty, 2019; Nhamo et al., 2024). Environmentally, digital tools such as smart energy systems and green ICT reduce resource consumption and carbon emissions, supporting sustainable campus operations (Abad-Segura et al., 2020; Filho et al., 2023; Redda, 2024).

Conversely, despite opportunities afforded by emerging digital technologies, there are inherent new risks introduced. This paper refers to digital risks aligned with sustainability as vulnerabilities introduced by DT that hinder the achievement of long-term social, economic and environmental objectives as described in frameworks such as the SDGs and NDP 2030. Technological dependence can exacerbate digital inequality, leaving under-resourced HEIs further behind (Mhlanga and Moloi, 2020). The overemphasis on technological efficiency may obscure social justice goals and human well-being (Sebola, 2022). Ethical and privacy concerns arise around data governance and AI, especially in contexts with weak regulatory oversight (Abulibdeh et al., 2024). These risks highlight the need for evidence-based strategies to balance innovation with sustainability and inclusion within SA's HE system.

1.4 The knowledge gap

Despite an expanding body of literature on digitalisation and sustainability in education, there are few integrated studies of sustainable digital transformation (SDT) in the SA HEI context. Existing studies tend to examine technological innovation without systematically addressing its environmental, economic, and social implications (Samuels and Singh, 2025; Teane and

Matlala 2025). Additionally, bibliometric trends reveal a lack of synthesised research, often overlooking institutional resilience, equity, and long-term governance outcomes (Naidoo et al., 2024).

Between January 2019 and September 2025, a period marked by the COVID-19 pandemic and post-pandemic digital acceleration, SA HEIs have undergone significant transformation. However, there is a lack of a comprehensive synthesis of how these changes have generated sustainable digital opportunities or introduced systemic risks. The present systematic review, thus, responds to the urgent need for synthesised insights to guide policy formulation, institutional strategy, and equitable digital adoption (Samuels and Singh, 2025). International bibliometric analysis indicates that interdisciplinary collaboration and sustainability remain core themes connecting DT and HE globally, with the United States, China, Spain, and South Africa prominently featured in the research output (Nurfadilah et al., 2025). This reflects the growing academic contributions of SA in this field. The DT in SA HEIs has been driven by the need to innovate during and after the COVID-19 pandemic, to maintain continuity in teaching, learning, and assessment. South African HEIs have since adopted hybrid teaching models and invested in digital technologies to improve educational access and quality, especially for disadvantaged students (Adeyemo, 2023; Redda, 2024).

1.5 Rationale and aim

There is a notable lack of reliable and relevant data for making decisions to achieve SDGs, as well as insufficient capacity to analyse the current data. Existing literature is fragmented, theoretically outdated, and insufficient. Between January 2019 and September 2025, SA HEIs found themselves at the crossroads of two transformative forces: the global imperative for sustainability and the rapid acceleration of DT. This period, significantly shaped by the COVID-19 pandemic and the rise of 4IR technologies, has catalysed significant changes in Higher Education (Samuels and Singh, 2025). Yet, the academic literature remains fragmented in its treatment of the sustainable digital risks specific to the SA context. South African HEIs attempting DT are likely to face similar challenges in data governance and analytical capabilities (Madon and Masiero, 2025). Researchers warn that many developing countries may not achieve the African Union's Agenda 2063, a framework for inclusive growth and sustainable development across the continent, due to weak multisectoral implementation strategies (Madon and Masiero, 2025; Siddiqi et al., 2020). Despite the accelerated pace with which digital connectivity has expanded its reach, there is an argument that the absence of policies and institutional arrangements hampers the availability of reliable and relevant data (Ajani, 2024), as well as the capacity to analyse these for decision-making to achieve the SDGs.

Even with the potential, many African nations, including SA, still lag behind developed countries in technological advancement due to factors such as unemployment, poverty, and energy crises (Oguntona and Akinradewo, 2025). However, studies rarely assess the depth of this integration or its direct empirical impact on student preparedness for the workforce (Naidoo et al., 2024). Addressing digital inequality is essential for SA to achieve its 2030 National Development Plan (NDP) objectives, which include reducing poverty. In ensuring access to quality education through digital means, HEIs contribute to broader social development and reduce inequality (Mateko et al., 2025). However, the literature lacks robust evaluations of how DT strategies are measured, particularly through indicators such as student satisfaction or integrated institutional performance metrics (Guo and Zeng, 2023). Literature often treats these opportunities as aspirational rather than operational. There is limited empirical evidence on their effectiveness or scalability (Samuels and Singh, 2025; Teane and Matlala, 2025).

In contrast, literature is more explicit about the risks that threaten the sustainability of DT in SA HEIs. Historical and socio-economic inequalities continue to shape access to digital resources, with the apartheid-era legacy still influencing institutional capacity and student inclusion. These structural barriers risk undermining the transformative potential of DT by reproducing existing disparities under the guise of innovation. According to Mateko et al. (2025), the poor policy implementation of post-apartheid has been a key stumbling block contributing to digital inequality. Bureaucratic impediments, such as lengthy approval processes for new technologies, discourage the effective implementation and dissemination of innovative practices within HEIs. Governance challenges, corruption, and maladministration in rural HEIs also hinder their ability to catch up with urban HEIs. This paper's objective is to synthesise literature on sustainable digital risks in South African HEIs between January 2019 and September 2025, identifying dominant risk patterns and providing actionable insights for policy and institutional strategies.

2 Survey of scholarship

Digital transformation is broadly understood as the strategic integration of digital technologies across all aspects of an organisation to enhance operations, improve user experiences, and foster innovation (Andrade and Gonçalo, 2021). Within SA HEIs, DT is increasingly aligned with the SDGs and environmental consciousness (Mateko et al., 2025; Mhlanga et al., 2022). This alignment reflects a growing recognition of the role HEIs play in advancing sustainability through education, research, and institutional governance. The COVID-19 pandemic significantly accelerated the adoption of digital technologies in SA HEIs, prompting a shift to online teaching and learning platforms and catalysing efforts to address digital inequality and funding constraints. However, the implementation of DT in SA remains complex and structurally uneven. Although digital technologies offer unprecedented opportunities for expanding access, improving quality, and institutional resilience, they also introduce systemic risks that, if left unaddressed, may deepen existing inequalities and compromise long-term sustainability.

2.1 Global and historical perspectives on connectivity and inclusion

Historically, digital connectivity initiatives dating back to the 1970s aimed to expand access to underserved populations. Over

time, these efforts have evolved to enable people to form networks and access personalised services. In recent years, international organisations have emphasised Information and Communication Technology (ICT) as a key driver of global development, particularly in support of the SDGs (Madon and Masiero, 2025). The DT process in SA HEIs aligns with global trends associated with the 4IR, incorporating advanced technologies such as AI, BDA, Blockchain, the Internet of Things (IoT), and immersive learning tools, including VR and AR. The emerging technologies improve educational delivery and institutional management (Samuels and Singh, 2025). These technologies not only are reshaping pedagogy, but are also redefining the strategic priorities of HE. A 2019 report by the International Telecommunication Union (ITU) highlights the scale of digital exclusion, noting that approximately 3.6 billion people remain offline, with access disparities across gender and geography (Vyas-Doorgapersad, 2022). As of 2024, Internet use in Africa was the lowest worldwide, at 38 per cent.

2.2 Sustainable digitalisation in policy and practice

Sustainable digital transformation is increasingly prioritised in policy and practice. The strategies emphasising environmentally conscious digital practices are embedded within the academic and operational frameworks (Genga and Babalola, 2025; Naidoo et al., 2024). In integrating green technologies into campus operations and curricula, HEIs can prepare students to address pressing environmental challenges. Integration of green technologies fosters a culture of innovation, resilience, and inclusivity. And this aligns institutional strategies with both 4IR demands and sustainability imperatives (Naidoo et al., 2024).

The pandemic catalysed digital adoption, requiring the HE sector to rethink traditional models and embrace more resilient and inclusive approaches (Redda, 2024). In response, policy frameworks have begun to encourage bottom-up collaborative strategies to address inequality through improved funding and infrastructure (Ndaba and Naidoo, 2024).

2.3 Barriers to implementation and capacity development

Enduring structural and policy challenges continue to limit the transformative potential of DT. These include inequitable digital infrastructure between urban and rural institutions, limited funding, and inconsistent national strategies (Mabasa and Maluka, 2024; Ndaba and Naidoo, 2024). Rural and historically disadvantaged institutions, in particular, struggle with inadequate physical and ICT infrastructure, and this impedes effective digital adoption and the maintenance of sustainable practices (Damoah et al., 2023). Inequitable access to technology among students and faculty continues to limit the effectiveness of digital learning. This highlights the importance of inclusive policy design and targeted institutional support (Samuels and Singh, 2025). The absence of comprehensive policy frameworks that align DT with sustainability objectives further restricts institutions from implementing cohesive strategies (Samuels and Singh, 2025). Continuous professional development (CPD) for faculty is essential to build digital literacy capacity and pedagogical competencies that support the integration of sustainability into digital education (Samuels and Singh, 2025).

2.4 Digital transformation and rural life

The intersection of DT and sustainable rural life is fundamentally interdisciplinary, bridging environmental, social, and economic domains. Digital inclusion and technological innovation are not just tools for connectivity; they serve as catalysts for economic opportunities in rural areas, improving resilience and sustainability (Amaliah et al., 2025). Access to ICT and financial technologies (FinTech) increases entrepreneurship and market participation, demonstrating the economic benefits of digitalisation in resource-limited contexts (Amaliah et al., 2025). At the macro level, digitalisation is widely recognised as a driver of economic growth in developing countries. It has the potential to improve productivity, reduce transaction costs, and expand access to global markets (Kruss et al., 2025). However, this potential is unevenly realised, given that it's impeded by structural inequalities that delimit who benefits and to what extent.

2.5 Strategic role of SA HEIs in national development

South African HEIs are uniquely positioned as drivers of knowledge production and economic development. This positioning makes the integration of DT and sustainability central to national resilience. Notwithstanding that, these institutions must navigate persistent socio-economic challenges, including digital divides, infrastructure deficits, and inequities in inclusion (Samuels and Singh, 2025). Rural HEIs face particularly acute barriers, including limited resources, inadequate infrastructure, and insufficient support for ICT training, all of which impede sustainable educational development (Damoah et al., 2023).

2.6 Towards inclusive and sustainable digital transformation

Literature underscores both the promise and complexity of DT in SA higher education. There are opportunities to improve student engagement, foster innovation, and strengthen global competitiveness through strategic reforms and aligned policies (Naidoo et al., 2024; Samuels and Singh, 2025). However, achieving these benefits requires addressing deep-rooted challenges in infrastructure, policy coherence, and capacity development. Ultimately, literature confirms that while DT presents an essential pathway to enhanced educational access and efficiency, its sustainable success in the SA HE context hinges entirely on mitigating persistent structural inequalities. This is an area where empirical synthesis and policy-aligned strategy remain conspicuously absent. Digital transformation in

HE is situated as a catalyst for sustainability; however, its success relies on mitigating institutional risks and bridging digital divides. Social, economic, and environmental sustainability goals are dependent on strong infrastructure, inclusivity, and capacity development. Without these, DT initiatives have the potential to reinforce inequalities and not promote resilience.

3 Methodology

3.1 SPIDER framework

Following the SPIDER framework, this paper addresses the research question "*What sustainable digital risks have emerged for SA HEIs, between 2019 and 2025?*" The SPIDER framework entails Sample, Phenomenon of Interest, Design, Evaluation, and Research type (Benavides et al., 2020), and was deemed appropriate for this systematic review paper. The SPIDER framework is often preferred in qualitative and mixed-method research because it emphasises the nature of the phenomenon and the research design (Cooke et al., 2012). It focuses on the Sample and Research type (S, R). The sample includes South African universities and colleges engaged in DT and sustainability initiatives. The Phenomenon of Interest (PI) focuses on the sustainable digital risks arising from digital transformation initiatives. The Design (D) includes a range of empirical and conceptual studies, including systematic reviews, case studies, and mixed-method research, that helped to capture the multidimensional nature of sustainability and digital innovation in HE. While the Evaluation (E) specifies the sustainability-related outcomes, including social, economic, environmental, and governance impacts, rather than temporal boundaries. The Research type (R) corresponds to the nature of the evidence, including qualitative, quantitative, and mixed-methods research. Exclusions encompass grey literature, such as dissertations, reports, conference abstracts, and non-empirical commentaries that lacked analytical or methodological rigour.

3.2 PRISMA approach

To ensure methodological rigour and transparency, the paper followed the PRISMA framework to guide the selection and screening of relevant publications (Tricco et al., 2018; Veronika et al., 2025). The limitation of a single-database search was addressed by selecting Elsevier's Scopus for its multidisciplinary coverage of education, ICT, and sustainability. The inclusion criteria targeted studies explicitly addressing sustainability and education. First, publications had to address explicitly related topics to sustainability and education. Using wildcard operators such as "*Sustainab**" *and "Educat**" enabled the retrieval of a wide vocabulary range of relevant terms. Secondly, to capture the full scope of digitalisation discourse, the search incorporated multiple related terms, including "*digital transformation*", "*digital technologies*", and "*educational technologies*". Thirdly, to ensure contextual alignment, the search targeted publications referencing educational institutions, operationalised through terms such as "*university*", "*college*", "*faculty*", and "*institute*". Lastly, activity-related terms such as "*scholar*", "*teach*", "*learn*", and "*research*" ensured relevance to HE practices.

An initial 214,535 records were identified; thereafter, the exclusion criteria were applied. A total of 126,059 records were removed prior to screening using automated Scopus subject classification and relevance filters, which excluded publications outside higher education, education, and sustainability contexts. After applying education-related subject filters, 88,476 records remained. Further filtering by affiliation country (South Africa), document type, language, and time period reduced the dataset to 521 records. Duplicate detection removed 221 records, leaving 300 studies for title and abstract screening. Following screening, 96 full-text articles were assessed for eligibility. Fifty-six studies were excluded for contextual irrelevance, insufficient focus on sustainability or digital transformation, or lack of empirical rigour. Ultimately, 40 studies met all inclusion criteria and were included in the final synthesis.

The review proceeded through four phases: identification, screening, eligibility, and inclusion. From an initial pool of 214,535 records, filters narrowed the dataset to 40 peer-reviewed studies that met all criteria. These publications form the basis for the present thematic and critical analysis of sustainable DT in SA HEIs (Figure 1).

3.3 PRISMA approach

Following established qualitative synthesis approaches, a multi-stage thematic synthesis was undertaken. Data were extracted from all included studies and imported into NVivo 14 for analysis. Open coding was conducted line by line, yielding 312 initial codes, which were then refined through axial coding into conceptually related categories. Five overarching themes were developed through iterative comparison and synthesis: deepening digital inequalities; infrastructural deficits; capacity and skills gaps; data governance and cybersecurity risks; and institutional and policy misalignment. A second reviewer independently coded 25% of the studies to enhance reliability, achieving a Cohen's Kappa of 0.82, indicating strong inter-rater agreement.

4 Literature findings

This study employed a thematic synthesis approach to explore sustainable digital risks within South African Higher Education Institutions (SA HEIs). Through an inductive analysis of qualitative data, recurring patterns and insights emerged across the reviewed literature, allowing themes to develop organically.

To ensure transparency and verifiability, a summary table of the 40 analysed articles is listed below. In addition, a formal evaluation of the quality of the included studies was undertaken to strengthen the conclusions through a critical appraisal step, using the CASP tool.

The details of the studies' characteristics are shown in Supplementary Table S1.

The summary list of all 40 analysed studies: (Amaliah et al., 2025; Andrade and Gonçalo, 2021; Carow et al., 2023; David, 2025a, b; Gumbi et al., 2024; Irene et al., 2025; Işık et al., 2024; Janse Van Rensburg et al., 2019; Kaeane and Molokomme, 2025; Kativhu, 2021; Kruss et al., 2025; Lembani et al., 2020; Lui et al., 2025; Madon and Masiero, 2025; Maree and Vos, 2021;

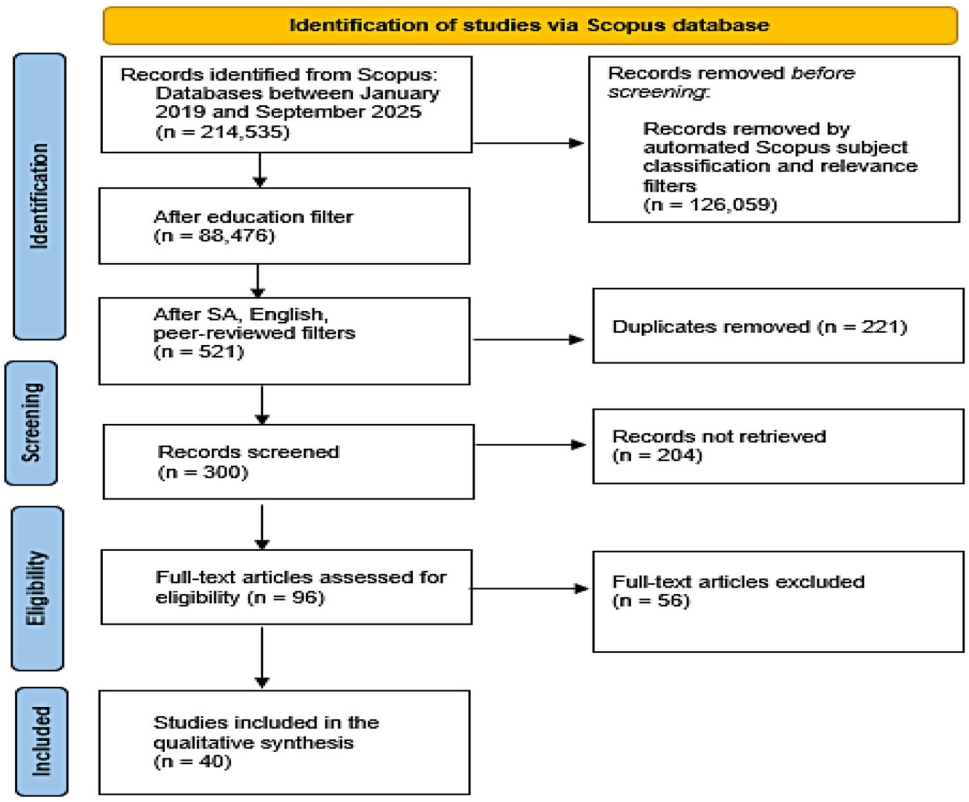

FIGURE 1
Process of the systematic literature review.

Masenya 2021a, b; Mateko et al., 2025; Mhlanga et al., 2022; Moloi and Salawu, 2022; Molokomme and Mahlakwana, 2025; Mpungose, 2025; Mthembu, 2022; Mudau et al., 2022; Mulaudzi, 2024; Naidoo, 2023; Ngoveni, 2025; Oguntona and Ohiomah, 2025; Patterson, 2021; Pretorius et al., 2021; Ramaila and Mavuru, 2023; Schaab et al., 2023; Stephen and Clinton, 2025; Timmis and Muhuro, 2019; Tshivhase and Bisschoff, 2023; van den Berg, 2019; van den Berg and Verster, 2022; Verster and van den Berg, 2022; Vyas-Doorgapersad, 2022).

4.1 Sustainable digital risks

The integration of digital technologies within SA HEIs is frequently celebrated as a lever for sustainability. However, the evidence suggests a more complex reality. Although digitalisation offers pathways to economic growth, educational equity, workforce development, and environmental resilience, these outcomes remain contingent on systemic reforms in policy, infrastructure, and human capacity. Without such alignment, sustainability risks remain aspirational rather than operational.

4.1.1 Deepening inequalities and infrastructure gaps

P A major concern in the DT of HEIs is the exacerbation of existing inequalities. Unequal access to connectivity, devices, and digital literacy continues to disadvantage rural and marginalised students, as this reinforces educational stratification (Carow et al., 2023; Mateko et al., 2025). High mobile data costs and unreliable infrastructure further compound these inequities, making DT aspirational rather than operational for many (Molokomme and Mahlakwana, 2025).

In rural HEIs, the persistence of infrastructural shortfalls represents systemic inequities embedded in historical financing patterns. This indicates that DT initiatives risk perpetuating existing disparities unless accompanied by targeted investment and policy reforms (Andrade and Gonçalo, 2021; David, 2025a; Kativhu, 2021; Mateko et al., 2025). These constraints limit institutions' ability to implement comprehensive DT strategies, let alone sustain ongoing technological upgrades. These constraints require considerable financial and logistical investment (Masenya, 2021a; Moloi and Salawu, 2022). Moreover, geopolitical and institutional disparities in Africa shape the uneven adoption of emerging technologies, underscoring the need for contextually appropriate localised strategies rather than universal models (Oguntona and Akinradewo, 2025).

4.1.2 Socio-economic inequalities and the digital divide

The digital divide remains not only a technological issue but a socio-economic phenomenon that perpetuates educational exclusion. Its persistence suggests that the SDGs cannot be achieved without addressing affordability and structural

inequality at a national level. Subsequently, this disproportionately affects students from rural and disadvantaged backgrounds (Carow et al., 2023; Irene et al., 2025; Lembani et al., 2020). These inequalities risk leading to educational exclusion, hindering the achievement of SDG 4 to promote inclusive and equitable education (Mateko et al., 2025).

Digital transformation initiatives could deepen exclusion if they are not strategically managed. High connectivity costs and limited digital infrastructure restrict participation in online learning (Molokomme and Mahlakwana, 2025; Mudau et al., 2022). The growing gap between well-resourced and under-resourced HEIs widens inequities, as many households cannot afford digital devices and consistent Internet access (Kativhu, 2021; Vyas-Doorgapersad, 2022). Consequently, digital inclusion should be considered a matter of equity and a fundamental right, not merely a convenience (Mudau et al., 2022).

4.1.3 Capacity deficits and faculty preparedness

A further challenge concerns the readiness of faculty and students to navigate a digitally driven educational environment. Limited faculty staff preparedness underscores misalignment between technological adoption and human capital development (Andrade and Gonçalo, 2021; Irene et al., 2025; Verster and van den Berg, 2022). This gap indicates that institutional strategies favour infrastructure over pedagogical capacity, undermining long-term sustainability. Providing tools alone is insufficient without the skills to use them effectively for teaching and learning. The present review shows that a significant portion of students lacked digital competencies (about 33%), which implies a need for frameworks that prioritise digital literacy training alongside device provision (Mudau et al., 2022). Despite limited professional development opportunities, faculty staff are restricted in their ability to integrate technology into teaching (David, 2025a; Kativhu, 2021). Cultural and structural barriers, along with a lack of confidence or self-efficacy in adopting new technologies, can impede the successful integration of digital tools within HEIs (Irene et al., 2025; Mhlanga et al., 2022; Moloi and Salawu, 2022). Overcoming these barriers requires ongoing training, institutional support, and a collegial environment that fosters pedagogical innovation.

4.1.4 Privacy, security, and ethical concerns

The prevalence of cybersecurity risks reveals a governance shortfall in HEIs, where rapid digital adoption outpaces regulatory frameworks. In the context of 4IR, these cybersecurity risks raise questions about institutional resilience and ethical accountability. Algorithmic bias, inadequate data protection, and system vulnerabilities threaten institutional integrity (Moloi and Salawu, 2022; Ngoveni, 2025). While technology improves access and efficiency, it cannot replace the critical role of educators in facilitating learning (Moloi and Salawu, 2022). Without adequate pedagogical integration, an overemphasis on technology risks diminishing learning quality.

Furthermore, digital repositories in many African HEIs face sustainability challenges due to low connectivity, outdated software, and power instability (Masenya, 2021a, b). Insufficient technical expertise and limited budgets exacerbate these issues, often resulting in reliance on donor funding and external consultants. The lack of awareness among academics about open-access initiatives and digital preservation practices further undermines institutional resilience (Masenya, 2021a, b).

Students often lack digital security awareness, and that also represents a vulnerability. A study conducted at the Durban University of Technology found that many students relied on others to manage their online security settings and found available information on digital safety confusing (Lui et al., 2025). The empirical evidence underscores the need for comprehensive digital literacy and cybersecurity education.

4.1.5 Institutional and policy misalignment

At a structural level, policy fragmentation reflects deeper governance challenges that hinder strategic alignment between national development goals and institutional digital agendas. This misalignment highlights the need for integrated policy instruments and cross-sector collaboration to achieve sustainability. Misalignment between digital connectivity policies and developmental objectives weakens institutional capacity to leverage technology effectively (Madon and Masiero, 2025; Vyas-Doorgapersad, 2022). Limited data analysis capabilities and unreliable infrastructure compound these challenges, particularly in low and middle-income contexts.

South African HEIs also lack structured contingency policies to support staff and students during disruptions such as power cuts, which severely affect online teaching, assessment, and engagement (Lui et al., 2025; Molokomme and Mahlakwana, 2025; Mpungose, 2025). Furthermore, the adoption of overly sophisticated technologies by resource-constrained institutions often leads to unsustainable investments and reliance on external vendors (Irene et al., 2025; Kativhu, 2021). Without sufficient internal capacity, the risk of mismanaging DT processes is high. This can lead to inefficient resource allocation and failed initiatives (Andrade and Gonçalo, 2021).

5 Interpretation of findings

Literature reveals a complex and often contradictory landscape surrounding DT in SA HEIs, particularly between urban and rural contexts. Students' difficulties with cybersecurity awareness and infrastructural challenges in under-resourced HEIs reflect broader systemic limitations rooted in historical inequities. These challenges echo long-documented constraints within SA's public university system, where persistent post-apartheid inequalities and chronic underfunding continue to shape the digital divide.

Depending on contextual capacity, governance coherence, and inclusivity, DT in SA HEIs emerges as a double-edged process capable of advancing sustainability while simultaneously undermining it. Infrastructural inequalities and connectivity gaps are consistently identified as central barriers to sustainable DT. However, literature extends beyond the surface-level diagnosis by situating these deficiencies within deeper, systemic, and historical contexts. The rapid pace of technological obsolescence, coupled with erratic power supply (e.g., inconsistent power cuts), costly maintenance, and the need for continuous upgrades, intensifies vulnerabilities, especially in institutions located outside major

urban metropolitan areas. Without sustained investment and coordinated policy support, digitalisation risks becoming unsustainable beyond short-term pilot initiatives.

Although faculty preparation and student digital literacy are often grounded in literature, it tends to overlook pedagogical design challenges that critically shape the quality of digital learning. The time-intensive nature of developing digital teaching materials, limited institutional support for content adaptation, and the discomfort students experience when navigating unfamiliar, interdisciplinary, or fully online environments are significant concerns. In addition, the loss of interpersonal learning nuances in digitally mediated settings raises questions about engagement, identity formation, and cognitive depth. These pedagogical risks complicate the assumption that DT inherently enhances the quality of teaching and learning.

Digital skill shortages among academic staff and students are widely acknowledged. Literature also provides a broader systemic framework that links institutional capacity gaps to a national workforce unprepared for the 4IR. Rural HEIs, in particular, face acute challenges in attracting and retaining qualified digital professionals. Marginalised groups, including women, continue to encounter barriers to digital inclusion, further exacerbating inequality. The need for a balance between technology investment and human capital development is critical; digital tools alone cannot drive sustainable transformation without robust competencies and institutional support.

Cybersecurity and privacy concerns are also prominent in literature. It highlights ethical and operational risks associated with digital repositories, data preservation, and algorithmic bias. The sustainability of digital infrastructures is threatened by hardware and software obsolescence, inadequate technical expertise, and reliance on donor-funded projects. Weak governance frameworks exacerbate these vulnerabilities, leaving institutions exposed to data loss, unauthorised access, and cyber threats. Students' limited awareness of data protection, particularly in institutions lacking cybersecurity training, further compounds these risks.

Institutional and policy misalignment is another recurring theme. Fragmented policymaking, weak data analytics capabilities, and dependence on external vendors undermine the coherence of DT strategies. The pursuit of sophisticated technologies by resource-constrained HEIs often results in unsustainable investments and reduced institutional autonomy. Overreliance on external consultants and proprietary systems is risky. That erodes local innovation capacity and reflects a deeper governance incoherence that hinders alignment with national development goals.

Literature demonstrates that sustainable digital risks in SA HEIs are multidimensional, interlinked, and systemic. These challenges are rooted in historical inequities, labour market deficiencies, ethical governance concerns, and the political economy of technology adoption, rather than technological scarcity. Addressing them requires a holistic, context-sensitive approach that integrates infrastructural investment, pedagogical innovation, human capital development, and inclusive governance.

6 Conclusions

This paper reveals that the sustainability of DT in South African higher education institutions is not shaped only by the adoption of digital technologies, but by the alignment of technical infrastructure, human capacity, and coherent policy frameworks. The presence of digital tools alone does not guarantee equitable or resilient educational outcomes. The paper highlights that risks such as infrastructural decay, uneven institutional capacity, and persistent digital inequities are symptomatic of deeper structural conditions that technology alone cannot resolve. The paper argues that sustainable DT must be approached as a developmental process. Digital transformation requires deliberate, inclusive, and context-sensitive strategies that embed equity, governance, and resilience at the core of institutional planning and decision-making. Without such integration, DT risks reinforcing existing inequalities and undermining long-term sustainability, particularly in rural and historically disadvantaged institutions.

To address these challenges, HEIs and policymakers must prioritise coordinated national strategies that promote inclusive governance, robust infrastructure, and pedagogical innovation. Investments in digital literacy, faculty development, and affordable access to devices and data are essential. To reduce barriers to participation, institutions must develop clear guidelines for technology deployment, ensure timely distribution of equipment, and advocate for zero-rated educational platforms.

Future research should empirically evaluate the outcomes of DT initiatives, particularly their impact on student learning, institutional performance, and workforce readiness. There is a need to explore the pedagogical design of digital learning environments, assess barriers to inclusion among marginalised groups, and develop sustainability metrics that capture environmental, social, and economic dimensions. Additionally, future studies should investigate governance models and policy instruments that facilitate sustainable DT in low-resource settings.

Ultimately, this paper calls for a paradigm shift in how DT is conceptualised and implemented in South African higher education institutions. Digital transformation must move beyond technological adoption and towards a holistic, equity-driven model that aligns digital innovation with the broader goals of sustainable development.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Author contributions

BN: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Validation, Visualization, Writing – original draft, Writing – review & editing. MP: Supervision, Writing – review & editing.

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Supplementary material

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/feduc.2026.1821997/full#supplementary-material

SUPPLEMENTARY TABLE S1
PRISMA checklist (Page et al., 2021).

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