The Qualitative evaluation of sustainable digital transformation strategies in South African higher education institutions

by

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DECLARATION

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I declare that

"The Qualitative evaluation of sustainable digital transformation strategies in South African higher education institutions",
is my own work, and all the sources that I have used or quoted have been indicated and acknowledged by means of complete references.

I declare that I have submitted the dissertation to originality checking software and that it meets the accepted requirements for originality.

I further declare that I have not previously submitted this work, or part of it, for examination at Unisa for another qualification or at any other higher education institution.

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ABSTRACT

The relevance of this thesis is in addressing a current information systems key issue. The research problem and key issue is how the sustainability of digital transformation strategies in higher education environments could be evaluated and achieved. The rapid advancement of digital technologies has revolutionised various sectors, including higher education. As part of this revolution, South African higher education institutions are increasingly embracing digital transformation strategies to enhance their operations and improve learning outcomes. However, evaluating the effectiveness of these strategies and ensuring their sustainability remains a challenge. To this point, the present study sought to address the problem by conceptualising a framework for evaluating and achieving sustainable digital transformation strategies, contextualised to the distinct functions and characteristics of South African TVET colleges.

In addressing the problem, the present study was underpinned by the Sustainable Information Systems theory, Triple Bottom Line theory, Resource-Based View theory, and Institutional Theory. Using a case study research strategy and inductive thematic analysis, supported by ATLAS.ti 25 Windows software. The study findings show that sustainable digital transformation strategies operate as dynamic, systematic processes in South African TVET colleges. The success of pedagogical shifts is not determined solely by technology integration, but is dynamically enabled or limited by five interconnected factors: strategic vision and leadership, institutional capacity, change management, digital teaching and learning, and financial and equity considerations. Aligning with global agendas such as the Sustainable Development Goals, the present study highlights the potential for economic growth and opportunities arising from investing in digital transformation. The thesis contribution is a framework that provides policymakers and practitioners with a foundation for evaluating and achieving sustainable digital transformation strategies in higher education, notably in South African TVET colleges.

Keywords: Digital transformation, Institutional Theory, Resource-Based View, Sustainable development goals, Sustainable Information Systems, TVET colleges, Triple Bottom Line

PEER-REVIEWED PUBLICATIONS FROM THE THESIS

Nthutang, B., Phahlane, M., and Malungana, L. 2026. Sustainability-Aligned Digital Risks in South African Higher Education: A Systematic Review (2019–2025). MDPI. *Sustainability*

Nthutang, B., Phahlane, M., and Malungana, L. 2026. Emerging Trends in Sustainable Digital Transformation Strategies in Higher Education Institutions: A Systematic Review. In the upcoming proceedings of *SITE 2026 - Society for Information Technology & Teacher Education conference*. Philadelphia, Pennsylvania, 23-27 March 2026

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Chapter One: Introduction and Background

1.1 Introduction

The relevance of this thesis is in addressing a current information systems key issue. The research problem and key issue is how the sustainability of digital transformation strategies in higher education environments could be evaluated and improved. Technical and Vocational Education and Training (TVET) colleges find themselves at an important fourth industrial revolution juncture. This is amidst heightened competition and the increasing demand to attract top-tier students and high-calibre academic talent, both within public and private Higher Education Institutions (HEIs). The research argument is that failure to adapt to these changing technological dynamics may result in reduced relevance. Therefore, for HEIs to endure and achieve academic outcomes through digital transformation (DT), they must employ strategic methods to identify the vital components within the higher education environments.

The present study sought to provide a theoretical and practical framework that addresses the comprehensive impact of DT on TVET colleges, taking into account their distinct functions and characteristics. The thesis provides a foundation for academics, practitioners, and policymakers to assess the effectiveness of sustainable digital transformation (SDT) strategies within South African public TVET colleges. The present study extracted valuable insights and lessons from lived experiences that may apply to other HEIs.

This chapter gives the background to the field of study, the background to the research problem and motivation, study purpose, goal, and objectives. It outlines the research questions, study delimitations, and finally, the significance of the study.

1.2 Background to the Field of Study

This section gives the background to the field of study by reviewing and defining the key terms and concepts making up the research topic. This is to help the reader understand the thesis title and the field studied.

Digital Technology is a combination of electronic devices, software, and systems that use binary code (0s and 1s) to process, transmit, and store data. This includes computers, smartphones, software applications, the Internet, and various other tools and technologies that facilitate digital transformation (George and Schillebeeckx, 2022).

Digital Transformation is organisational change triggered by digital technologies. It is the inclusive alignment of digital technologies, strategies, and processes across different facets of an institution or system to change how it is conducted and present value. It often involves adopting new technologies and digital platforms to improve efficiency, enhance customer experiences, and stay competitive in the digital age (Nadkarni and Prügl, 2021).

Digital Transformation Strategy is an institution's comprehensive plan that supports its institutional characteristics, addresses specific digital technology-based goals, and serves as a blueprint for guiding transformations resulting from the integration of digital technologies. It also plays a critical role in governing institutions' operations post-transformation (Braga Tadeu, de Castro Moura Duarte, Taurion and Jamil, 2019; Vial, 2019).

Digitalisation is the broader transformation of processes, activities, or entire systems through the use of digital technologies. It involves incorporating digital technology into a product or service.

Digitisation is a fundamental step in enabling digital transformation (Vial, 2019; Feroz, Zo, Eom and Chiravuri, 2023). Digitisation is a component of digitalisation, a method of converting analogue information, procedures, or techniques into digital form. It involves using automated routines and tasks for storing, processing, and transmitting data and information (Vial, 2019; Feroz et al., 2023).

Sustainability is the capacity to maintain and continue in a particular state, process, or system over an extended period without exhausting resources, inflicting damage to the environment, or jeopardising the welfare of those yet to come. In the context of digital transformation, sustainability can pertain to the long-term viability and effectiveness of digital initiatives and strategies (Freeman, Dmytriyev and Phillips, 2021).

Technical and Vocational Education and Training (TVET) college is an institution that offers tertiary or post-secondary education, providing technical or vocational training. This type of education is inherently technical, aiming to equip individuals with skills for a specific profession. The primary goal is to enable individuals to secure employment and sustain a livelihood (Alao and Brink, 2022).

1.2.1 Digital Transformation and TVET colleges

Digital transformation, which involves integrating digital technology into all facets of an organisation, is reshaping how TVET colleges operate and deliver education (Abdul Razak, Noordin and Abdul Khanan, 2022). However, the successful implementation and sustainability of these DT strategies hinge on various factors, encompassing institutional capacity, stakeholder engagement, and

the alignment of digital initiatives with the colleges' strategic objectives. While the integration of digital skills into TVET delivery is acknowledged, the holistic mechanisms for building digital competence within the TVET system require further investigation (Zhong and Juwaheer, 2024).

Higher education institutions are critical in moulding a sustainable outlook by providing people with the knowledge, skills, and values necessary to address environmental, social, and economic challenges. Mhlanga, Denhere and Moloi (2022) assert that South Africa should focus on building digital capabilities and skills to bridge the existing gaps in digital technology. Furthermore, Mhlanga et al. (2022) highlight that lessons learned from the Coronavirus Disease 2019 (COVID-19) pandemic have underscored the importance of DT across all sectors of the economy. Lessons learned indicate that South Africa requires substantial investment in improving its digital framework, supporting research and development of new technologies, and training its workforce to adapt to the changing digital landscape. In doing so, South Africa can become more competitive and create new opportunities for economic growth and sustainable development. The Fourth Industrial Revolution (4IR) and the digital revolution have facilitated widespread and unrestricted access to information worldwide (Mhlanga et al., 2022).

Although international literature frequently uses the term HEIs to mainly refer to universities, the current study focuses on South African public TVET colleges. References to HEIs are used only when the cited literature applies to universities, TVET colleges, and Community Education and Training (CET) colleges. Where findings relate specifically to TVET colleges, the term TVET colleges is used to avoid ambiguity.

1.2.2 Sustainability and digital transformation strategies in higher education

The impact of the changing digital landscape must align with the fourth Sustainable Development Goal (SDG) of the 2030 Agenda for Sustainable Development (Quality Education), as set by the United Nations. The fourth SDG, specifically 4.3, calls for ensuring equal access to affordable, quality technical, vocational, and tertiary education for both women and men by 2030 (United Nations, 2015). As per Manda and Backhouse (2017) remarking that as far back as 1998, the government of South Africa identified the prospects and difficulties inherent with 4IR and thus responded with guidelines and procedures addressing the inclusivity of DT.

The South African development plan, the National Development Plan (NDP), introduced in 2012, is an example of acknowledging DT as critical in transforming the public service. The NDP is a comprehensive economic strategy designed to transform South Africa from a developing nation into an advanced, first-world country by 2030. This ambitious plan aspires to achieve the twin goals of

eradicating poverty and lessening inequality within the next decade through the collaborative endeavours of the entire South African population (Alenezi and Akour, 2023).

Digital transformation has risen to a paramount position for HEIs, as these institutions are vital to the growth and empowerment of societies. Therefore, investing in education is essential for achieving sustainable development (SD) and building a knowledge-based economy (Alenezi, Wardat and Akour, 2023). The current study relies upon best practices in the utilisation of Information and Communication Technology (ICT) in South Africa. Lusigi (2019) recommends addressing deficiencies in policy coherence, digital literacy, and investment. A skilled workforce is necessary for advancing and implementing new technologies, innovation, and creativity. As such, countries that invest in their education systems and have leading HEIs are better positioned to diversify their economies and achieve sustained economic growth.

1.3 Background to the Research Problem

This section provides the background to the research problem and gives motivation for the present study by discussing the study location and context, challenges and issues, and articulating the research knowledge gaps.

National assessments, such as the Digital Transformation Readiness Index (DXRI), indicate that although progress is being made, TVET colleges have not yet reached the level of digital maturity required to fully leverage DT opportunities (BMR and GIZ, 2022; Tustin and van Aardt, 2022). This present study is motivated by the need to address these gaps by analysing and evaluating how DT is unfolding within TVET colleges.

1.3.1 Study location and context

This present study was conducted within the South African TVET college sector, which is distinguished by its institutional distinctiveness. Factors contributing to the uniqueness of TVET colleges include specific program offerings, local community skill requirements, and the campuses' geographic location, which are often closely linked to the types of businesses prevalent in those areas. The present study builds on the knowledge that South African TVET colleges have embarked on the DT journey. Hence, the study is centred on understanding the evaluation methods and criteria used by South African TVET colleges in terms of sustainability and effectiveness of DT strategies.

The present study location is deliberately public TVET colleges in South Africa. These colleges had previously been involved in Department of Higher Education and Training (DHET) initiatives to integrate sustainability, specifically those influenced by the Skills for Green Jobs (S4GJ) programme

(Singh and Feuerriegel, 2013). The initiative was initially piloted in select colleges under S4GJ, then later scaled to all public TVET colleges (Freimann and Magnus, 2023). The location is TVET colleges with experience or exposure to relevant digital transformation initiatives, ensuring alignment with the study objectives (Noble and Smith, 2025; Polat, 2025).

The South African educational landscape comprises 50 public TVET colleges with 364 registered campuses nationwide. KwaZulu-Natal Province leads the pack with nine TVET colleges, while the Northern Cape Province has the fewest, with two. The Mpumalanga and North West provinces each have three, with the remaining five provinces maintaining an average of four to seven colleges each (ETDP SETA, 2024).

The latest TVET college statistics for March 2023 show a surge in staff numbers, from 18,396 in 2019 to 20,045 in 2021. Moreover, a higher proportion of females (54%) was employed than males (46%). This growth coincides with a significant rise in student enrolment. In 2021, TVET colleges welcomed 589,083 students, representing a 30.2% increase (136,806) compared to 2020 (452,277) (ETDP SETA, 2024). While females outnumbered males across nearly all qualification types, the diverse specialities offered by these institutions nonetheless fueled growing interest in TVET education.

Although these institutions have diverse specialities, they are marked by their institutional distinctiveness. Factors contributing to this uniqueness include the specific program offerings, the local community's skill requirements, and the campuses' geographical position, which are often closely linked to the types of businesses prevalent in those areas (Nkalane, 2018; Qolamani and Mohammed, 2023). However, the TVET sector is chosen purposefully as the research area because these institutions possess the infrastructure and personnel required for DT. It is assumed that some DT strategies have been implemented per government regulations.

1.3.2 Digital Transformation Challenges and Issues in Higher Educational Settings

Digitalisation and technology integration, often referred to as DT, involves the use of digital technology at every stage of the educational process. Alenezi and Akour (2023) define DT as incorporating digital technology throughout the educational process. This transformation is viewed as a means to enhance the educational experience for both educators and students, enabling greater flexibility and accessibility. Sustainable digital transformation strategies are developed to ensure that the integration of digital technologies aligns with long-term sustainability goals. These strategies aim to minimise negative environmental and social impacts and promote positive outcomes over time (Castro Benavides, Arias and Burgos, 2022).

MaryAnne Gobble (2018) emphasises that "true digitalization" or digital transformation is a structured journey guided by a digital strategy, and institutions that embrace digital innovation tend to achieve superior results. Similarly, Castro Benavides et al. (2022) have shown that institutions embracing DT achieve better results than those that do not. Van Staden and Naidoo (2022) focused on the challenges students face in rural regions of South Africa, particularly the risk of exclusion from online learning due to limited Internet access and technological resources. Studying the effects of SDT strategies in public TVET colleges can provide valuable social resources, known as social capital, that can be harnessed and leveraged by contemporary DT systems (Mohamed Hashim, Tlemsani and Matthews, 2022a).

Stroumpoulis and Kopanaki (2022) state that SDGs from the United Nations will continue to guide and shape international efforts and initiatives to achieve a more sustainable and equitable world over the next decade, up to 2030. The present study aligns with the fourth SDG, which aims to ensure equal access to affordable and quality technical, vocational, and tertiary education for both men and women by 2030. This SDG promotes inclusivity, gender equality, and improved opportunities for social and economic development (Nkambule and Ngubane, 2023; Sibiya, 2024).

The significance of a well-defined digital strategy is further substantiated by Pillay, Padayachee, Govender, and Ndabandaba (2021), who posit that DT offers lecturers the advantage of using various digital tools. To better manage and support their students, they must cater to individual learning needs and enhance educational outcomes. Students can benefit from faculty members' expertise, guidance, and mentorship through digital technology, leading to a more enriching educational journey (Mhlanga, 2020). Literature has demonstrated that digital tools and platforms facilitate interaction, engagement, and collaboration, addressing challenges such as inadequate preparation and socio-economic factors (Chukwuere, 2020; Mhlanga and Moloi, 2020).

The utilisation of technology reduces reliance on physical resources and facilities in traditional educational settings, enabling education beyond physical capacity and potentially stimulating innovation in the sector (Alenezi et al., 2023). The existing literature highlights a need for DT in educational settings.

The South African TVET sector has undergone significant changes, transitioning from a system focused on staffing to one geared towards further education and training, and ultimately, TVET in the post-democratic age (Motlhanke and Naong, 2021).

1.3.3 Relevance of the Study Location, DT Challenges and Issues

Castro Benavides et al. (2022) report that the DT decision variables identified within HEIs extend beyond technological advancements. Digital Transformation has a profound impact, reshaping the meaning and influencing various aspects within these institutions. This includes the institutional culture, administrative and educational activities, assessment methods, pedagogical approaches, teaching, research, extension activities, administrative procedures, and the individuals involved in the institution.

Recent academic efforts have primarily focused on offering advice on specific aspects of DT rather than on the comprehensive development of an organisation-wide, SDT strategy. Drawing from Hess, Matt, Benlian and Wiesböck (2016), the present study put forward four foundational components for constructing a sustainable DT strategy.

1.3.3.1 Four fundamental components constituting a DT strategy

a) The use of technology reveals an institution's strategy and capacity for exploring and utilising new digital technologies. This decision variable concerns how South African HEIs leverage 4IR technologies, such as Blockchain Technology (BT), the Internet of Things (IoT), and Big Data Analytics (BDA). Evaluating this decision variable involves assessing how these institutions adopt and effectively utilise these technologies to enhance their educational offerings, administrative processes, and overall operations.

b) Value creation changes show DT's impact on an institution's value creation. This decision variable corresponds to the impact of DT on the value creation of HEIs. In this context, it would involve evaluating how DT initiatives contribute to enhanced value creation, including factors like improved educational outcomes, better student experiences, and increased research productivity.

c) Structural changes suggest adjustments in the organisation's structure, procedures, and skill sets required to cope with new technologies. South African HEIs may need significant structural changes to accommodate and capitalise on new digital technologies. Evaluation in this decision variable would entail assessing the effectiveness of organisational changes, processes, and skill development efforts in adapting to and exploiting these technologies.

d) Financial features decision variable concerns an institution's imperative to respond to challenges in its principal business and its capacity to fund a DT initiative. This decision variable encompasses the financial needs and capabilities of HEIs in response to DT. Evaluating this decision variable would involve examining the financial resources available for DT projects and the institution's ability

to manage and allocate these resources effectively. It might also include assessing whether DT initiatives help address economic challenges, such as attracting and retaining students.

1.3.3.2 Incorporation of Sustainability Strategies

This sub-section sheds light on the current state of DT in South African higher education and identifies knowledge gaps for policymakers, educators, and administrators as they navigate the complexities of the digital transformation journey.

South African Pro-Digitalisation Landscape

South African pro-digitalisation policies and status as an emerging market make it a relevant and valuable setting for a study on DT in higher education, including its broader economic implications. In incorporating online teaching into their curriculum, institutions can develop their digital capabilities and equip students with the necessary digital skills for thriving in the 21st-century workforce. This may also help institutions be better prepared for future disruptions, such as natural disasters or pandemics. In anticipation of a better future, the NDP emphasises inclusive growth, job creation, improving education and skills advancement, addressing social hardships, as well as promoting sustainable growth. The NDP seeks to achieve these goals through various strategies, such as infrastructure development, investment in human capital, and fostering social cohesion (Manda and Backhouse, 2018).

The NDP recognises DT as a key driver of South Africa's development. It calls for investments in digital infrastructure, skills development, and the adoption of digital technologies across sectors to realise the digital economy's full potential and ensure inclusive growth. In the South African NDP framework, DT is seen as a catalyst for job creation, innovation, and productivity enhancement (Mhlanga and Moloi, 2020). The NDP plan emphasises improving digital infrastructure, expanding broadband connectivity, and enhancing digital literacy and skills among the population. In doing so, the NDP aims to bridge the digital divide, thus guaranteeing that every citizen has equal access to digital opportunities.

The South African NDP also highlights the significance of leveraging digital technologies in several sectors, including education, healthcare, agriculture, and government services, to improve efficiency and foster citizen engagement (Chukwuere, 2020). As per the African Union, DT is a catalyst for fostering innovative and sustainable advancement in Africa. It generates employment opportunities, combats poverty, diminishes inequality, and aids in the realisation of Agenda 2063 as well as the SDGs (UNION, AFRIKA and AFRICANA, 2024). On the contrary, the obstacles to Internet access in Africa include ineffective regulatory frameworks, the absence of cohesive regional infrastructure strategies, and political intervention.

As highlighted by Vial (2019), the intrinsic value of digital technologies to an institution is minimal. The real value emerges when these technologies are integrated with human resources and relationship assets, allowing the institution to discover novel methods of value creation (Jyoti and Efpraxia, 2023). This aligns with the longstanding view that institutional change emerges over time. Manda and Backhouse (2018) advise that collaboration among stakeholders is essential to overcome challenges that may jeopardise South Africa's aspiration for an inclusive digital society by 2030. The identified obstacles include governance issues, unsupportive political will, policy prioritisation, and poor monitoring and evaluation. Recommendations emphasise the assessment of requirements and the role of educational technology centres in implementing digitalised curricula.

Digital Transformation Strategies in South African Higher Education Institutions

The University of South Africa's Bureau of Market Research (BMR) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) conducted a study that indicates that public TVET colleges in South Africa have an overall Digital Transformation Readiness Index score of 54.61 (BMR and GIZ, 2022; Tustin and van Aardt, 2022). This score falls short of the desired level for implementing DT strategies. As well as the circumstances necessary for promoting digital readiness, they have not yet reached the desired level (Montenegro-Rueda and Fernández-Cerero, 2023; Chen and Chan, 2024). Furthermore, the study suggests that while some of the essential conditions for transformation are in place, they are only met to a certain extent. This implies that, while progress is being made, there is still significant room for improvement in achieving the conditions needed for successful DT.

As stated by Stroumpoulis and Kopanaki (2022), integrating several technologies has the ability and power to create significant capabilities within institutions. These enhanced capabilities, in turn, contribute to improved sustainable performances and enable the formulation of sustainable strategies. Ultimately, adopting DT can potentially improve an institution's market position. This suggests that institutions embracing digital technologies may gain a competitive advantage and achieve better sustainability and strategic outcomes. However, the literature indicates this process is still evolving, and many questions remain unanswered (Vaska, Massaro, Bagarotto and Dal Mas, 2021). Furthermore, Vaska et al. (2021) argue that DT and the opportunities it creates across sectors are still in their early stages of development.

While some essential conditions for transformation are in place, they are only partially met, suggesting room for improvement in achieving the conditions for successful DT. A study by (Ritala, Baiyere, Hughes, and Kraus (2021) emphasises the role of the human element in digital strategy and the adoption of digital technologies. The human component of realising digital strategy objectives remains an enigma. Some academics have expressed negative reactions to alignment with the 4IR

through the online systems implemented by their educational institutions. Some researchers, especially Khoza and Mpungose (2022), highlight the various Learning Management Systems (LMS) in teaching and learning introduced to HEIs canvas by the University of Denver in the USA; THUTO in Lesotho by the National University of Lesotho; and in South Africa, MyUNISA by the University of South Africa; Moodle by the University of KwaZulu-Natal; VULA by the University of Cape Town; Blackboard by the Durban University of Technology.

Mbanga and Mtembu (2020) suggest that it is essential to assess the requirements of the institution, academics, and students before introducing digital learning. They found that the views of 125 academics demonstrated enthusiasm and commitment to implementing digital learning at the TVET site, despite structural challenges and procedures that suggested otherwise. Academics accustomed to traditional methods may face challenges in adopting advanced digital technologies (Mpungose, 2020). Additionally, Khoza and Mpungose (2022) questioned the need to explore what drives academics to embrace a fully digitalised curriculum and recommended the creation of educational technology centres to lead implementation. In their study, academics often find themselves in the dual role of educators and educational technologists.

Fourth Industrial Revolution Technologies in Higher Education

The 4IR technologies include Blockchain Technology (BT), Internet of Things (IoT), and Big Data Analytics (BDA). These information systems technologies vary in terms of design and functionality. For instance, BT design includes four key characteristics: non-localisation (decentralisation), security, auditability, and smart execution (Saberi, Kouhizadeh, Sarkis and Shen, 2019; Feroz et al., 2023). BT can revolutionise the tracking of textbooks and assignments throughout the entire value chain. The academic community can appreciate the importance of ensuring transparency and authenticity, as these factors influence the accessibility, integrity, and sustainability of educational resources.

The Internet of Things (IoT) enables information sharing amongst connected stakeholders through the Internet by utilising sensor-based technology. It is a new information technology still in the early stages of development, and has not formed a complete technology framework or obtained a standardised, unified architecture (Stroumpoulis and Kopanaki, 2022). In educational terms, IoT devices can be employed to monitor the condition of equipment and infrastructure in real-time. Furthermore, IoT generates a vast amount of data. In leveraging data analytics tools, TVET colleges can gain insights into student performance, resource utilisation, and overall operational efficiency (Mbanga and Mtembu, 2020). The consequence of using digital technologies is the huge amount of information and data available.

The collection, extraction, and storage of large datasets are related to BDA (Stroumpoulis and Kopanaki, 2022). BDA can analyse student performance data to identify individual learning preferences and patterns. Early intervention strategies can be implemented to provide additional support to these students, ultimately catering to the unique needs and strengths of each student (Braga Tadeu et al., 2019).

Korachi and Bounabat (2019) claim that institutions with well-established IT governance structures are more inclined to participate in digital initiatives and are better positioned for DT. Additionally, there is a need for an assessment system, presented as an Integrated Methodological Framework for Digital Transformation Strategy Building (IMFDTS), which includes Key Performance Indicators (KPIs), a dashboard, and a maturity model (Braga Tadeu et al., 2019). Though lacking in the sustainability aspect, this framework aims to assess the outcomes and advancements of DT, providing a means to continuously enhance the DT strategy.

Denhere and Moloi (2021a) note that there is a need to employ the Anchored Instruction theory and the Connectivism theory in the South African context. This aligns with the perspective expressed by Paryono (2017) in Indonesia, which emphasises the importance of aligning students, the academic community, and local businesses. This alignment is fundamental for ensuring that South African TVET colleges collaborate effectively in training and maintaining industry-relevant standards, ultimately contributing to the development of essential skills in TVET alums.

1.3.4 Research knowledge gaps

This sub-section identifies research knowledge gaps from existing literature and observation of the study location and context. These knowledge gaps motivated the present study.

The unique blend of technological, cultural, and operational shifts within TVET colleges necessitates a nuanced understanding and tailored assessment methods. Digital transformation transcends traditional institutional boundaries and requires a comprehensive educational strategy. The existing literature has highlighted the profound impact of DT on various sectors, yet there are research knowledge gaps concerning the specific dynamics within TVET colleges (Mohamed Hashim et al., 2022a). The current research landscape falls short in addressing the perspectives of the academic community and students who grapple with challenges related to the sustainability of DT strategies, such as unequal access to resources and the need for adequate training and support.

Moreover, the present study challenges extend to the imperative for TVET colleges to continually adapt and evolve, underlining the urgency for South African TVET colleges to remain relevant amid digital disruptions. The gap lies in the need for a theoretical framework that encapsulates the holistic

impact of DT on TVET colleges, considering their unique functions and characteristics. There is a need for a study that delves into the effects of transformation on technology usage, educational outcomes, alignment with global trends and sustainability goals, and readiness and improvement strategies within TVET colleges in South Africa (Gobble, 2018; Castro Benavides et al., 2022).

In essence, the identified research knowledge gaps converge on the need for a contextualised framework that addresses the intricate layers of DT in TVET colleges, going beyond technological advancements to encompass cultural, pedagogical, and operational dimensions (Hess et al., 2016; Castro Benavides et al., 2022). This knowledge gap presents an opportunity for the present study to contribute to the development of guidelines, rules, procedures, and toolkit components that enhance digital readiness and align with the unique challenges and objectives of TVET colleges (Montenegro-Rueda and Fernández-Cerero, 2023; Chen and Chan, 2024).

1.3.4.1 Brief overview of the identified knowledge gaps and challenges

Gap One - *Technology usage*. Exploring and identifying how technology is being used in higher education institutions and how that is aligned with DT. This will help to understand how these institutions should react in order to prepare the 21st-century workforce (Mhlanga, 2020; Khoza and Mpungose, 2022; Mohamed Hashim et al., 2022a).

Gap Two - *Effect of DT on education*. Understanding how DT influences institutional teaching, learning, and research outcomes has become a field worth studying. It is worthwhile to explore the ability of higher education institutions to integrate technology and keep up with global trends effectively (Alenezi and Akour, 2023; Alenezi et al., 2023).

Gap Three - *Alignment with global trends and sustainability goals*. South African TVET institutions need to align with international trends to keep their focus on the institutional goals and purpose, and to remain relevant and competitive (Stroumpoulis and Kopanaki, 2022). Not much is known about the perspectives of the academic community and students who are affected daily by challenges associated with the sustainability of DT strategies, such as unequal access to resources and the need for adequate training and support (Lusigi, 2019; Pillay et al., 2021).

Gap Four - *Digital Transformation Readiness Assessment and Improvement.* The present study focuses on refining the 2022 baseline self-assessment of DT readiness in public TVET colleges in South Africa, as outlined in the executive summary of the methodology (Tustin and van Aardt, 2022). Specifically, the present study refines the methodological guidelines, rules, procedures, and toolkit components. The key observations from this executive summary are that while there is some progress and readiness for DT in TVET colleges, it falls short of the desired level, particularly in terms of

implementing strategies, achieving outcomes, and enhancing overall digital readiness (Montenegro-Rueda and Fernández-Cerero, 2023; Chen and Chan, 2024).

Further efforts and improvements are necessary to effectively meet SDT goals. The identified gaps encompass the need for a nuanced understanding and tailored assessment methods, a comprehensive educational strategy, a theoretical framework that addresses specific dynamics within TVET colleges, consideration of the perspectives of academic communities and students, adaptation and evolution of TVET colleges, and a theoretical understanding that covers various dimensions of DT within these institutions.

a) Theoretical knowledge gap

Several scholars, particularly Grant and Osanloo (2014), underlined the functional theories as the "blueprint" or roadmap for research. It is a resource that researchers draw upon, much as they would borrow materials to construct their own unique "house" of research. This theory forms the bedrock on which a research project is built, providing the framework that guides a researcher's philosophical, epistemological, methodological, and analytical decisions (Grant and Osanloo, 2014). The present study triangulates multiple theories to provide a comprehensive understanding of SDT strategies in HEIs. Theories shape researchers' thought processes, guide their interpretations of the world, and inform the decisions they make throughout their research endeavours (Saunders, Lewis and Thornhill, 2023).

b) Practical knowledge gap

Through amalgamating insights from various theories and viewpoints, there is a need to construct a more holistic comprehension of SDT strategies in public TVET colleges. This entails considering both the inward and outward aspects influencing this transformation, along with the ethical and societal dimensions that come into play. South African TVET colleges lack practical tools, criteria, or models for evaluating DT effectiveness or sustainability, limiting their ability to measure progress or inform continuous improvement. That is, there are inadequate frameworks that could inform the practical evaluation and enhancement of SDT strategies, notably in the context of TVET colleges. The figure below gives an example of a lacking practical framework that could inform practice.

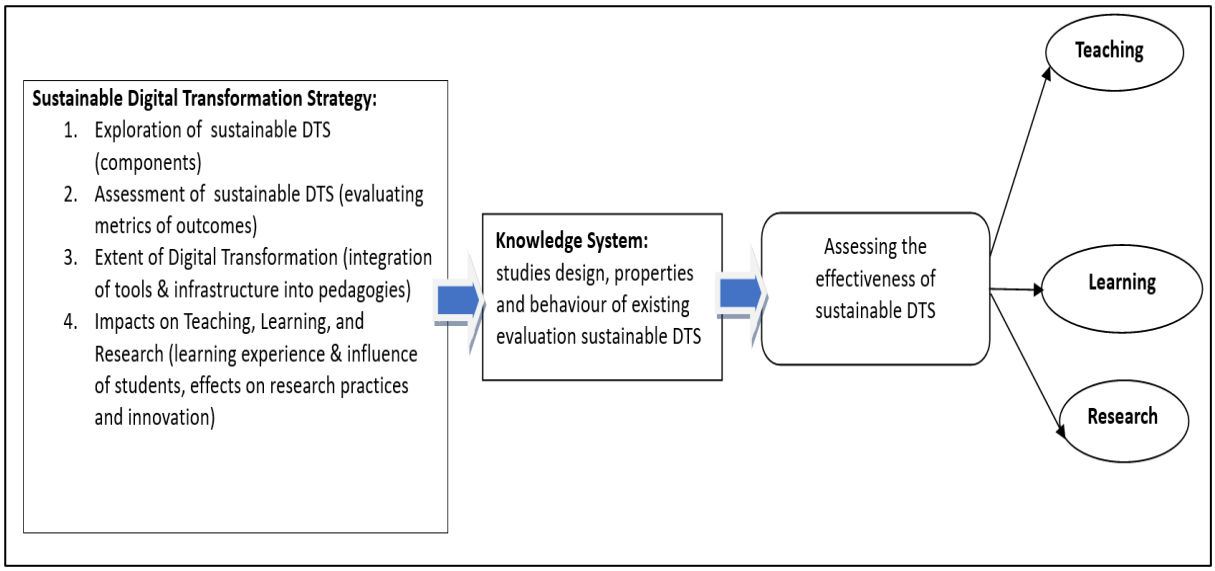


Figure 1: A practical framework for assessing the effectiveness of SDT strategies within South African public TVET colleges (Mohamed Hashim et al., 2022a)

Despite previous research efforts, Korachi and Bounabat (2019) state that there is a lack of systematic and rigorous academic studies that specify guidelines for institutions on how to construct and assess DT strategies. The existing knowledge in this area is considered insufficient, and there is a need for both academic researchers and practitioners to delve deeper into this field to gain clearer insights and develop practical guidelines. There is no documented practical approach for assessing SDT strategies in South African TVET colleges.

c) Methodological knowledge gap

There is a research methodological gap in studying and evaluating real-world SDT strategies to provide descriptive insights and policy recommendations. There is no known study that follows an interpretive philosophy and employs a multiple-case study to explore and describe SDT strategies, notably in the context of South African TVET colleges. Quantitative surveys do not provide the necessary descriptions to achieve SDT strategies.

d) Contextual knowledge gap

The research problem lies in the absence of a documented contextualised approach to assessing the effectiveness of SDT strategies within South African TVET colleges. South African TVET colleges are unique with respect to their socio-economic backgrounds, and therefore, there is a need to explore and evaluate sustainable DT strategies within that context.

1.4 Problem Statement

With the preceding challenges and issues, as well as the identified research knowledge gaps, there is a need to study and understand the current sustainability conditions and the implications of DT strategies in the higher education environment, notably TVET colleges. The research problem is that higher education institutions (HEIs) lack the "know what" and the "know how" to sustainable digital transformation strategies. Existing literature is inadequate in addressing this problem. HEIs do not possess a comprehensive understanding to be able to harness their current SDT strategies across teaching, learning, and research workforce (Mabidi, 2024; Mutakwa and Muloiwa-Klenam, 2025). There is ineffective technology integration, global competitiveness and failure to produce fully prepared graduates for the 21st-century workforce (Aleryani, 2024; Rivett and Pashapa, 2026). There is insufficient knowledge and understanding concerning the utilisation of technology in these institutions and the extent to which DT could influence the outcomes of teaching, learning, and research. This problem poses a potential obstacle for an institution to effectively incorporate technology and stay abreast of global trends, potentially compromising its overall competitiveness and hindering its capacity to yield a 21st-century workforce of well-prepared graduates. To address this current problem, the present study conceptualises a framework for sustainable digital transformation strategies in the context of South African higher education institutions.

1.5 The research argument

The research argument is that understanding context is key to addressing digital transformation challenges and issues in HEIs. Information systems research suggests that context is important, as what works in developed countries and private organisations may not work the same in South African public higher education institutions' workforce (Mahlangu and Mtshali, 2024; Samuels and Singh, 2025). Therefore, it is relevant to study and address the research problem in the context in which it happens. Technology is being increasingly utilised to facilitate teaching, learning, and research in South African HEIs, as DT continues to impact the country's higher education landscape (Mabasa and Maluka, 2024; Ndaba and Naidoo, 2024). DT is primarily driven by volatility, uncertainty, complexity, and ambiguity. This argument suggests that strategic technology integration is essential to ensuring that South African HEIs remain competitive and relevant.

1.6 Study purpose, goal, and objectives

The **study purpose** was to explore, evaluate, and describe the sustainability of DT strategies in South African public TVET colleges.

The **study goal** was to conceptualise an integrated framework informing how SDT strategies may be implemented, experienced, and evaluated across higher education institutions.

Study objectives:

1. To identify and analyse the critical success factors and barriers influencing the implementation of Sustainable Digital Transformation strategies in South African TVET colleges.
2. To explore and describe technology usage in TVET colleges to improve higher education, and to examine whether digital transformation has broader implications for institutional governance.
3. To examine and describe the influence of leadership and governance on sustainable digital transformation, in South African TVET colleges.
4. To develop recommendations for realising, evaluating and enhancing sustainable digital transformation strategies and initiatives in South African TVET colleges.

1.7 Research questions (PRQ and SRQs)

Primary research question

How should sustainable digital transformation strategies and initiatives be realised, evaluated and enhanced in the context of South African higher education institutions?

Secondary research questions

1. What are the enablers (critical success factors) and the barriers influencing sustainable digital transformation strategies in South African TVET colleges?

2. What and how is technology used in TVET colleges to improve higher education, and what are the digital transformation implications for institutional governance?

3. How do leadership and governance influence sustainable digital transformation in the context of TVET colleges in South Africa?

4. How can sustainable digital transformation strategies and initiatives be realised, evaluated and improved in the context of South African TVET colleges?

1.8 Study delimitations

The present study focused on the current information systems key issue with regard to SDT strategies, in the context of South African HEIs. The study did not analyse the actual digital technologies, nor did it analyse specific digital transformation strategies and initiatives. The study did not include all South African higher education institutions but rather employed TVET colleges as the study location and context. That is, the present is a case study of TVET colleges that may not be generalisable to all higher education institutions.

This study is delimited to public TVET colleges in South Africa and is a qualitative multiple-case study; the findings are contextually bounded. Consequently, the study is delimited to Qualitative data only, participants' perceptions, experiences, and interpretations, as well as documented institutional strategies, plans, and policy sources. Only institutions that have participated in the DHET sustainability-oriented initiatives were included, particularly those influenced by the S4GJ and DT-related programmes. These institutions were purposively selected as they possess existing exposure to transformation efforts relevant to the study's focus on SDT strategies. Private TVET colleges, community colleges, universities, and other post-school institutions are deliberately excluded, as they fall outside the central purpose of evaluating SDT strategies within the public TVET sector.

The study is delimited to members of the academic community (both academic and non-academic staff) who have been employed at a participating TVET college for at least 1 year. This boundary ensured that participants possessed adequate institutional experience to provide meaningful insights into SDT processes. The participants' roles were purposefully included as they are directly involved in decision-making, implementation, or pedagogical engagement with DT initiatives. Students and other administrative categories were excluded as their functions do not align with the research objectives.

1.9 Significance and relevance of the present study

The present study is significant and relevant as it addresses a current information systems key issue, in the emerging field of SDT strategies and initiatives, notably in South African higher education. It is contributing to the body of knowledge practically, methodologically, contextually, and theoretically. These contributions are outlined and discussed in the last chapter.

1.10 Summary of the chapter

This chapter introduced and provided the background to the thesis. It gave the background to the field studied, the background to the research problem, which provided the motivation for the present study.

The chapter identified the research knowledge gaps and provided the research problem. The study's purpose, goal, objectives, and research questions were outlined. Finally, the study delimitations and significance of the study were provided.

1.11 Thesis structure

The rest of the thesis is structured as follows:

Chapter Two: Sustainable Digital Transformation in Higher Education Institutions and Related Works surveys the scholarship and systematically reviews literature that gives the theoretical and practical foundation for the present study.

Chapter Three: Landscape of the South African TVET sector and Related Works surveys the scholarship and systematically reviews literature that gives the theoretical and practical foundation for the present study.

Chapter Four: Underpinning Theories and the Conceptual Research Framework for SDT in South African HEIs discusses the underpinning theories and provides the conceptual research framework that guided the present study.

Chapter Five: Research Methodology describes the research methodology followed in conducting the present study.

Chapter Six: Data Analysis and Discussion of Findings analyses data and discusses the study findings.

Chapter Seven: Interpretation of findings and the SDT framework interprets the study findings and provides the framework for evaluating and improving SDT strategies, in the context of South African higher education institutions. The contributions of the study are discussed.

Chapter Eight: Evaluation of the Research evaluates the research journey and concludes the thesis.

Chapter Two: Sustainable Digital Transformation in Higher Education Institutions and Related Works

The preceding chapter gave the introduction and provided the background to the research problem. This chapter reviews related works and subsequently provides background literature on Sustainable Digital Transformation strategies, highlighting trends and critical topics, including information technologies, DT, innovation, and sustainability. Section 2.2 discusses the connection between DT and sustainability, whereas Section 2.3 debates the integration of DT and sustainability in HEIs. Section 2.4 explores the sustainability of DT strategies, while Section 2.5 concludes the chapter.

2.1 Introduction

As the world enters the Fourth Industrial Revolution (4IR), higher education institutions (HEIs) face significant challenges in preparing students for the rapidly evolving job market (Biclesanu, Savastano, Chinie and Anagnoste, 2023; Abulibdeh, Zaidan and Abulibdeh, 2024). The process of ensuring HEI readiness encompasses various aspects, including the availability of ICT infrastructure, the competencies of academic staff and students in using learning technologies, and the flexibility of the curriculum to adapt to new learning regimes (Holler, Brändle and Zinn, 2023; Timbula and Marvadi, 2023; Rivera-Gutiérrez, Higuera-Zimbrón and Argüello, 2024).

Recent studies have highlighted the importance of using technology to support experiential learning in HEIs (Mohamed Hashim, Tlemsani and Matthews, 2022b; Vlizos, Kotsopoulos and Christodoulou, 2024). Prominent theorists Strielkowski, Korneeva and Gorina (2022) note that current education systems often reflect outdated industrial-era values and methods. Building on this, education must balance local and global efforts to meet human needs sustainably. Digital transformation in education is essential for adapting to modern challenges. Organisations like the World Bank support educational access and skills development (Strielkowski et al., 2022). Integration of innovative technologies, such as customisable scaffolding, automated reflection, and learning analytics, can facilitate real-world learning experiences (Tsai, Poquet, Gašević, Dawson and Pardo, 2019; Van Der Graaf, Raković, Fan, Lim, Singh, Bannert, Gašević and Molenaar, 2023). Moreover, the application of information technology to education has become increasingly fundamental in the age of 4IR. The transformation of education is essential to adapting educational systems to meet the demands of a rapidly changing world. According to Shenkoya and Kim (2023), the application of information technology in education is not only beneficial but essential in the age of the 4IR. It enhances learning experiences, promotes innovation, and prepares students for future challenges in the workforce. Some HEIs have

already implemented innovative approaches, such as providing information technology-based educational facilities, developing lecturers' capacity in information technology, and collaborating with the industrial sector to integrate technology-based learning opportunities (Setiawan, Iswoyo and Pujiastuti, 2020; Denhere and Moloi, 2021b)

Feroz et al. (2023) define Sustainable Digital Transformation as a transformative process whereby institutions modify their core strategies and business models to align with sustainability goals. The institutional modification is enabled by digital technologies, including Artificial Intelligence (AI), Big Data, the Internet of Things (IoT), Cloud Computing (CC), Blockchain, Mobile, and Social media technologies. Digital transformation is an emerging topic in academia. Digital technologies like Big Data analytics (BDA) and Machine Learning (ML) are making it essential for institutions to reconsider or enhance their business models and way of operations to compete and survive in the ever-evolving industries and markets (Feroz et al., 2023; Meijer, 2024). At the institutional level, Hess et al. (2016) contend that institutions must innovate with these technologies by developing strategies that embrace the implications of digital transformation and drive better operational performance.

Lü (2024) defines digitalisation as a broad and deep process involving the transformation of traditional, non-digital forms of information, operations, or processes into digital form, to achieve efficient processing, storage, transmission, and application of digital technologies such as computers and the Internet. The transformation process of digitalisation is not limited to changes at the technological and production levels, but also involves a deeper restructuring of enterprises, industries, and the socio-economic structure of society as a whole (Robertsone and Lapiņa, 2023; Lü, 2024).

Scholars recognise that DT involves a fundamental shift in the way organisations integrate processes, people, and technology to optimise operations (Kraus, Jones, Kailer, Weinmann, Chaparro-Banegas and Roig-Tierno, 2021; Nadkarni and Prügl, 2021). The DT process represents a comprehensive redesign aimed at enhancing organisational efficiency and effectiveness. Robertsone and Lapiņa (2023) claim that the DT process involves digital technologies that lead to organisational changes and, more importantly, improvements. DT can reshape an institution’s business model and operations (Feroz et al., 2023; Meijer, 2024).

Sustainability is undeniably among the most rapidly expanding phenomena (Muschert and Ragnedda, 2021; Guandalini, 2022). The objective of sustainability in higher education is to eliminate waste and ensure the use and longevity of resources (Santolin, Hameed, Urbinati and Lazzarotti, 2023; Vlachopoulos, Thorkelsdóttir, Schina and Jónsdóttir, 2023). However, a critical gap exists in the understanding of applying this knowledge to effectively use digital technologies (George, Lakhani

and Puranam, 2020). Samuel, Lucivero, and Somavilla (2022) claim that the term ‘sustainability’ has a long history of being a complex and unclear concept. Samuel et al. (2022) note that this complexity arises because sustainability does not have a fixed, universally agreed-upon definition. Instead, its meaning is shaped by the context in which it is applied and the perspectives of those interpreting or implementing it (Guandalini, 2022; Robertsone and Lapiņa, 2023). Consequently, the present study adopts an interpretive approach to capture context-dependent meanings across stakeholder groups.

There is a significant research knowledge gap in specific discussions on DT strategies within HEIs, different from broader trends in implementing Industry 4.0 and Society 5.0 (Sá and Serpa, 2020; Strielkowski et al., 2022; Machado, Duarte, Amaral and Araújol, 2024). Similar to DT, there is a notable knowledge gap in research, particularly in regions where environmental management initiatives may be less prevalent. The lack of focus on sustainability initiatives highlights the need for more in-depth studies to understand the barriers and opportunities for sustainable practices in these contexts (Pascual, 2023; Tshivhase and Bisschoff, 2023a). These broader trends extend from dynamics of digital contextual factors on business practices, manufacturing, agriculture, transportation, and energy in the context of DT, to name a few, to the interdisciplinary nature of many sustainability initiatives in HEIs (Wang and Mei, 2024).

Many topical trends discussed in the literature on SDT strategies are highly relevant for DT strategies within Higher Education Institutions. Examples include information technologies, DT itself, innovation, and sustainability. Antonopoulou, Begkos and Zhu (2023) suggest that DT in higher education has improved academic operations processes and given HEIs a competitive edge in the evolving global market. Through digitalisation, organisations can better grasp market opportunities, improve competitiveness, and achieve sustainable development (Vandevenne, Riel and Poels, 2023; Lü, 2024).

It is noted by Shenkoya and Kim (2023) that, beyond core educational activities, digital technologies like augmented reality (AR) can enhance public engagement with educational institutions. For instance, the study on cultural heritage preservation using Virtual Reality (VR) installations offers insights into how HEIs should use similar technologies (Vlizos et al., 2024). Another instance is by Lichtenthaler (2022), who examined the efficiency of data management and its role in creating shared value for businesses. Through prioritising data management efficiency, HEIs can streamline operations, reduce costs, and improve decision-making, leading to more effective and efficient administrative processes, ultimately benefiting students and faculty. Efficient data management can facilitate innovation by enabling data-driven insights.

Institutions can encourage faculty and students to use data analytics to develop innovative solutions to educational challenges, leading to new programs, services, and partnerships. In improving DT efforts and data management practices, HEIs can respond more effectively to market changes and evolving student needs. Higher education institutions can use these insights to explore how DT can contribute to sustainability goals in diverse fields, such as energy, transportation, and manufacturing, which are also relevant to their educational and research missions (Timbula and Marvadi, 2023).

Guandalini (2022) explores the relationship between DT and sustainability, directly relevant to the overarching theme of SDT strategies. Higher education institutions are increasingly integrating sustainability principles into their DT efforts, which makes this present study highly pertinent. Guandalini (2022) systematically reviewed academic articles to consolidate and identify thematic connections. Through synthesising the findings of 153 academic articles, Guandalini (2022) provides a comprehensive overview of the research landscape on digital sustainability. The study identified research gaps to advance the development of the topic and to inform future research directions in the field of SDT.

The research agenda proposed by the present study has important theoretical and practical implications that may inform academic scholarship and practical decision-making in various domains. Higher education institutions can benefit from the insights generated by the present study to improve their SDT strategies. The study findings on digital sustainability are applied to the context of HEIs, even though also applicable to businesses in general. Understanding these knowledge gaps is fundamental for shaping the focus of literature and ensuring that HEIs address current knowledge gaps, thereby contributing meaningfully to the existing body of knowledge.

The following section examines the link between digital transformation and sustainability, focusing on the Triple Bottom Line, a sustainability framework that evaluates an institution's performance based on three dimensions, namely, social, economic, and environmental impact.

2.2 Linking digital transformation and sustainability

Prior research by Guandalini (2022) envisioned the potential of digital technology to boost economic growth while reducing environmental harm. This potential extends to knowledge sharing, better management, and broader access, benefiting businesses and institutions (George et al., 2020; Di Vaio, Palladino, Pezzi and Kalisz, 2021). The recent surge in the adoption of digital technologies within HEIs emphasises the need to understand their environmental impact (Meijer, 2024). The present study contributes to a deeper understanding of the interconnectedness of DT and sustainability.

In the current study, HEIs are seen to significantly contribute to the Sustainable Development Goals (SDGs) through education, research, and community involvement (Caiado, Scavarda, Gavião, Ivson, de Mattos Nascimento and Garza-Reyes, 2022). Digital transformation is a fundamental strategy for organisations aiming to meet the SDGs. While the 2030 Agenda offers a foundational framework, HEIs can enhance their efforts by incorporating additional frameworks and objectives. Achieving sustainability necessitates a comprehensive approach that addresses environmental, social, and economic dimensions. This multifaceted strategy allows the 2030 Agenda to serve as a basis that is further elaborated by various frameworks and initiatives (Elmassah and Mohieldin, 2019; Sun, Wang, Wang and Sun, 2023). Strielkowski et al. (2022) posit that initiatives like Agenda 21 emphasise the role of environmental education in societal change. While sustainability education initially focused on environmental protection, this lacks broader social justice aspects.

Mapingire, Smuts, and Van der Merwe (2022) categorise DT into technological, organisational, and social thematic, emphasising the utilisation of digital technologies and their effects on business processes, operations, products, and customer experience. Sustainable digital transformation strategies are holistic procedures governing an organisation's path toward DT (Su, Wu and Tan, 2024). These strategies involve anticipating risks, identifying opportunities, and developing strategies based on digital technologies. These strategies should align with an organisation's overall goals and involve all relevant departments (Mapingire et al., 2022). Yang and Jin (2024) state that, with the development of DT, digitalisation is profoundly changing the way organisations function and the market's competitive landscape through technological and business model innovation. Through DT, enterprises can optimise business processes and improve efficiency with the help of advanced information technology, which enhances their ongoing effectiveness. Chanias, Myers, and Hess (2019) further state that DT strategies differ from Information Technology (IT) or Information Systems (IS) strategies when focusing primarily on the business and its customers, rather than on technology. Westergren, Mähler, and Jadaan (2024) highlight how DT processes surpass previous IT use in terms of speed and scope. Hamadi and El-Den (2024) posit that, given its interdisciplinary nature, IS is well-positioned to address sustainability challenges and mitigate negative environmental impacts on organisations, corporations, and educational institutions. Consequently, Hess et al. (2016) have underscored the importance of developing IS-based strategies that harmonise organisational change with IT enablers. Therefore, in the context of HEIs, DT strategies deal with curriculum development, student support systems, and teaching and learning (Holler et al., 2023; Timbula and Marvadi, 2023).

Developing a conceptual framework for sustainable digital learning can be valuable to understand and evaluate existing strategies (Holler et al., 2023; Matli and Phurutsi, 2023; Kana and Letaba,

2024). From Australia, Hamadi and El-Den (2024) address sustainable digital learning in higher education as a critical aspect of the topic. Digital learning combines face-to-face instruction with online learning elements. The strategy combines traditional face-to-face classroom methods with online learning activities and digital resources. The goal is to provide a more flexible and engaging learning experience. Digital learning technologies are the foundations of online and blended learning approaches in higher education. Hamadi and El-Den (2024) offer an opportunity to compare and evaluate the effectiveness of existing SDT strategies in HEIs. They propose a framework resulting from a comprehensive integrative review, followed by a thematic analysis of relevant sources, which outlines common research themes in the literature and identifies significant areas for future research. Hamadi and El-Den (2024) highlight five dimensions of sustainability and specific challenges to digitalisation, namely social, economic, environmental, human, and technical.

The growing interest in digital sustainability, especially its connection to global development goals, underscores the need for a focused review of HEIs (Sun et al., 2023; Abulibdeh et al., 2024). Massive Open Online Courses (MOOCs) are considered digital strategies in education. While digital strategies like MOOCs may not be directly applicable, MOOCs highlight the importance of prioritising sustainability planning (Kennedy and Laurillard, 2019). These digital strategies leverage digital platforms and technologies to provide large-scale, accessible, and often free online courses to a broad audience. MOOCs are part of a broader strategy to use digital tools to enhance learning, increase access to education, and support lifelong learning. Similarly, new digital tools such as Small Private Online Courses (SPOCs) and social media have created innovative opportunities for companies (Lü, 2024). MOOCs represent a shift toward DT in education, using online resources, multimedia content, interactive forums, and other digital tools to deliver education innovatively.

2.3 Integrating digital transformation and sustainability in HEIs

Robertsone and Lapiņa (2023) showed that using DT to focus on sustainable organisational gains improves the organisation's competitive advantage. Higher education institutions also impact the environment by consuming natural resources, such as energy and water, and by producing waste. Higher education institutions should actively work to reduce their environmental impact. In the latter case, to carry out their activities, HEIs occupy spaces, are consumers of water and energy, are significant consumers of paper and office equipment, manage catering activities, generate waste, wastewater, and produce air emissions (Del Giudice, Chierici, Mazzucchelli and Fiano, 2020). The structures within HEIs can be examples of practising sustainability when implementing sustainability policies during these listed activities.

Incorporating sustainability into DT involves principles that efficiently influence aspects of the environment, society, and economy (Alojail and Khan, 2023). SDT strategies should consider social, economic, environmental, and, at times, political issues. Based on these studies, taking a circular approach when implementing DT is essential, considering socioeconomic factors and their environmental impact. However, Brenner and Hartl (2021) find that digitalisation significantly affects ecological and economic sustainability, but has a less significant effect on social sustainability.

Similar views that SDT strategies should consider social, economic, and environmental issues are also expressed regarding circularity (Liu, Trevisan, Yang and Mascarenhas, 2022; Agrawal, Yadav, Majumdar, Kumar, Luthra and Garza-Reyes, 2023). A circular approach to DT fosters individuals' socioeconomic factors and the environment (Payer, Quelhas and Bergiante, 2024). Circularity in DT means taking a holistic approach that encompasses all spheres of sustainability. According to Lü (2024), there is "environmental balance, economic prosperity, and social responsibility", forming the triple bottom line as a responsible business goal supporting sustainable development. It is also vital that when public institutions like TVET colleges implement digital tools in teaching and learning, the three spheres of sustainability- economy, society, and the environment- are considered. The following section will combine social and economic factors into socioeconomic factors, which are usually intertwined.

2.3.1 The social impact of digital transformation in HEIs

Strielkowski et al. (2022) highlight the need for educational institutions to adapt to new technologies and methodologies to remain effective, particularly in light of the COVID-19 pandemic, which accelerated the shift to online and home-based learning. Drawing on data from researchers and lecturers in the Czech Republic and Russia, the researchers critique modernisation theory and emphasise the interconnectedness of societies, which is foundational to understanding how educational systems can adapt to global challenges (Callinicos, 1985; Castells, 2000). The conclusions drawn from Strielkowski et al. (2022) offer policy implications for educational institutions and governments. In suggesting that HEIs should embrace digital technologies and become engines of innovation, Strielkowski et al. (2022) advocate for a proactive approach to educational reform that aligns with the SDGs.

To fully implement SDT strategies in HEIs, educators must consider students' abilities, particularly those relating to their learning needs and background (Elia, Solazzo, Lerro, Pigni and Tucci, 2024). The digital transformation canvas: A conceptual framework for leading the digital transformation process. As observed by Hamadi and El-Den (2024), while educators may possess extensive expertise and skills within their respective disciplines, they may lack the ability to effectively design and

implement digital technologies in their teaching environments. This knowledge gap can negatively impact students' learning experiences, as the improper integration of digital tools may hinder rather than enhance the educational process. There are varying degrees of access to ICT resources between individuals from different backgrounds, homes, enterprises, or regions (Ahmed, Nathaniel and Shahbaz, 2021). In some scenarios, specific regions or socioeconomic backgrounds may find it easy to network, improve money flow, attract talent, and accumulate financial resources and technology due to the implementation processes that foster DT (Barykin, Sergeev, Kapustina, Fedotov, Matchinov and Plaza, 2023).

Studies suggest that digitalisation can promote equity, inclusion, and sustainability in education (Sá and Serpa, 2020; Jekabsone and Gudele, 2023; Shenkoya and Kim, 2023). When nurturing DT across industries, advancing inclusion among individuals from diverse backgrounds is also important. Individuals should have equal access to resources such as high-speed Internet access, e-learning or m-learning platforms, and digital literacy (Cadiz, Manuel, Reyes, Natividad and Ibarra, 2024). At the South African level, approximately 90% of households need an Internet connection at home, mainly due to the need for effective implementation of policies and procedures that promote digital inclusion (Aruleba and Jere, 2022). Students raised in areas with sufficient digital resources generally possess an advantage over their counterparts in regions lacking such resources, a phenomenon referred to as 'the digital divide' (Faloye and Ajayi, 2021; Rooein, Bianchini, Leotta, Mecella, Paolini and Pernici, 2021).

The digital divide refers to the gap between individuals with access to and the ability to use technology and those without it (Masonta, 2023). Inclusion is essential to developing the right digital literacy skills so that people can use resources efficiently to promote SDT. Digital literacy is closely related to several SDGs, including Goal 4 (Quality Education) and Goal 9 (Industry, Innovation and Infrastructure). Through enhancing digital literacy among students, HEIs can contribute to achieving these SDGs (Chen, Chen, Lin, Yan, Huang and Huang, 2023). Su et al. (2024) suggest that it is essential that governments at various levels encourage various industries to pursue DT initiatives while also implementing policies that consider the local conditions of various individuals.

Over the past few years, public institutions have witnessed changes that have led to the adoption of digital technology, driven by societal and technological trends (Wang, Li, Tian, Zakuan, and Rani, 2023). A significant change that has contributed to the trend of DT is the lockdown during the COVID-19 pandemic. For instance, the COVID-19 pandemic demonstrated the importance of students in public institutions developing their digital skills to effectively navigate online learning tools (Inan Karagul, Seker, and Aykut, 2021; Selwyn, 2021). Furthermore, the COVID-19 pandemic

has underscored the importance of higher education institutions being more proactive in integrating online learning platforms in anticipation of future pandemics (Cloete and Ndlovu, 2023). During the South African COVID-19 pandemic lockdown, students from secondary schools in Gauteng lacked adequate access to technological resources at home, which severely affected their academic performance (Chisango and Marongwe, 2021). The South African lockdowns during COVID-19 made it evident that there is a digital divide between institutions in specific communities and regions.

One significant challenge in implementing SDT strategies in higher education is access to resources that facilitate digital learning, such as a reliable Internet connection, especially for students from rural communities (Faloye and Ajayi, 2021; Rooein et al., 2021; Matli and Phurutsi, 2023). It can be inferred that participation in online or blended learning may be feasible for only a subset of students in Africa, rather than for all. Implementing SDT necessitates strategies to combat digital exclusion, particularly in impoverished communities in South Africa, and to bridge the digital divide (Khoza, 2024; Mesuwini and Mokoena, 2024). Eden, Chisom and Adeniyi (2024) suggest that the implementation of SDT strategies needs sustainable resources and considerations regarding socioeconomic challenges.

2.3.2 Leveraging digital technology for a circular economy in HEIs

Agrawal et al. (2023) discuss the integration of circular economy (CE) practices and disruptive digital technologies in supply chains (SCs), highlighting their potential to address sustainability challenges. Agrawal et al. (2023) contribute to understanding SDT strategies through a state-of-the-art review of 187 articles, identifying 49 drivers and enablers and 25 barriers and challenges. Additionally, Agrawal et al. (2023) presented a framework to clarify the relationship between disruptive digital technologies and CE performance in SC. The integrative framework by Agrawal et al. (2023) delineates the way forward toward a digital technology-enabled circular SC, based on the findings of the current study. Agrawal et al. (2023) state that a significant obstacle to adopting CE practices is the lack of awareness regarding the advantages of using digital technologies. Additionally, the absence of a standardised framework further hinders the widespread implementation of CE initiatives. The framework comprises four primary elements: barriers or challenges, drivers and enablers, digital technology interventions, and circular performance. Agrawal et al. (2023) further demonstrate that the use of digital technologies to facilitate CE practices can significantly enhance circularity performance in SC across various dimensions, including sustainability culture, waste management, resource optimisation, product life cycle, occupational health, technological advancement, social performance, product safety and quality, including customer loyalty and satisfaction.

Researchers have explored integrating digital technologies with CE principles (Bressanelli Adrodegari, Pigosso and Parida, 2022). The authors' conceptual framework and definition of the smart circular economy paradigm provide a theoretical basis for understanding how digital technologies can drive sustainable practices. The authors' conceptual framework for the smart circular economy paradigm informs the development and implementation of SDT strategies in HEIs. The research can guide future investigations within HEIs that seek to enhance sustainability through DT, as it identified promising research directions to advance the field of the smart circular economy (Payer et al., 2024). Including the need to explore the synergistic potential of different digital technologies and assess their environmental impact. Bressanelli et al. (2022) advocate for transitioning from exploratory and descriptive research to confirmatory and prescriptive studies. Bressanelli et al.'s (2022) conceptual framework of the smart circular economy paradigm can inform the design and conduct of future research in the HEI context.

(Okai-Ugbaje, Ardzejewska and Imran (2022) state that effectively using big data, an organisation can drive environmental innovation, achieving higher sustainable performance. The process will not only help improve the core competitiveness of the organisation and increase economic efficiency, but also reduce pollution and enhance the organisation's performance in environmental and social responsibility (Lü, 2024). Del Giudice et al. (2020) report that Big Data plays a moderating role in the relationship between circular economy, human resource management, and firm performance within a circular economy supply chain. This aspect is particularly relevant in the context of DT, as Big Data analytics plays a foundational role in optimising supply chain processes and driving sustainability initiatives. Insights from the present study on the role of Big Data may inform SDT strategies in HEIs seeking to leverage data-driven approaches for sustainability. The present study uses data from an online survey and multiple regression analysis to analyse the relationships between circular economy practices and firm performance. This methodological rigour improves the credibility of the findings and contributes to the robustness of the investigation. Del Giudice et al. (2020) show that circular economy practices can sustainably improve firm performance, indicating positive sustainability outcomes for organisations. Higher education institutions can apply these findings of how Big Data can be leveraged to support firm circular economy supply chain performance in environmental, social and economic terms to their sustainability initiatives. Higher education institutions can implement circular economy practices within their operations, such as waste reduction and recycling, and leverage Big Data to optimise resource use (Meijer, 2024). Additionally, HEIs can educate future leaders on the principles of the circular economy, thereby expanding their impact.

HEIs are increasingly adopting digital technologies to drive sustainability initiatives, and understanding how digital functions can enhance circular economy strategies is pertinent to HEIs' digital transformation efforts. Liu et al. (2022) undertook research involving the intersection of digital technology and circular economy strategies. They directly address sustainability through the lens of the circular economy, a critical concept for sustainable practices. Although the primary focus is on businesses, the findings are applicable to various sectors, including higher education. The researchers identified 13 critical functions of digital technologies relevant to circular economy strategies, such as Data Collection and Integration, Data Analysis, and Automation. The 13 critical functions provide valuable information on the specific capabilities of digital technologies that can contribute to sustainability objectives. This information may inform decision-making processes in HEIs when selecting and implementing SDT strategies. Liu et al. (2022) also present a framework outlining seven mechanisms by which digital technologies can bolster various circular economy strategies. The presented framework provides a systematic approach to understanding the potential effects of digital technologies on circularity and can assist in strategic planning in HEIs.

Higher Education Institutions have a significant role to play in promoting CE principles. Santolin et al. (2023) directly explore the enablers of CE, the key drivers for sustainable development. Although Santolin et al. (2023) focused on SMEs, CE enablers and digital technologies also apply to HEIs. The study highlights digital technologies as one of the most impactful CE enablers in the post-pandemic era. Using the fuzzy TOPSIS methodology to add rigour to the analysis, enhancing the credibility of the findings. The fuzzy TOPSIS methodology provides a systematic, robust approach for identifying the most impactful CE enablers. The study assesses the impact of the COVID-19 pandemic on CE enablers, providing insight into how organisations, including HEIs, can adapt their strategies in response to global disruptions. However, the focus is on business practices and general trends in digitisation, rather than the educational landscape and sustainability efforts within HEIs. Understanding the changes brought about by the pandemic informs future DT efforts in higher education. Higher education institutions are well-positioned to develop and implement digital solutions for CE initiatives. Higher education institutions can leverage digital technologies to support CE practices within their operations, for example, waste reduction, resource management, and sustainable procurement. Higher education institutions are increasingly focusing on integrating digital technologies to advance sustainability goals, and understanding their role in promoting circularity is essential. The findings of Santolin et al. (2023) are transferable to HEIs, particularly regarding digitalisation strategies. Higher education contexts can adapt many DT strategies designed for SMEs.

Higher education institutions have a strategic position to develop and implement digital solutions for CE initiatives. Institutions are uniquely positioned to leverage their resources, expertise, and innovative capabilities to drive sustainability efforts. Through integrating digital technologies into their operations, HEIs can enhance their contributions to CE practices and foster a culture of sustainability within their communities. The COVID-19 pandemic has underscored the importance of DT in HEIs, prompting many institutions to adopt digital tools that facilitate learning and operational efficiency (Selwyn, 2021). This shift not only supports educational delivery but also aligns with broader sustainability goals by reducing resource consumption and waste (Meijer, 2024). Moreover, HEIs can lead by example, showcasing successful digital solutions that other sectors can emulate. The institutions' role as educators places them in a pivotal position to train future leaders in sustainable practices, ensuring that the next generation is equipped with the knowledge and skills necessary to navigate the challenges of a rapidly changing world.

2.3.3 Environmental impact of digitalisation on education

Understanding educators' knowledge, experiences, and opinions about the environmental consequences of digitalisation in school education offers valuable insights. These perspectives shed light on the broader implications of digitalisation, including its impact on higher education, and inform strategies for SDT across all educational levels, such as HEIs (Hamadi and El-Den, 2024). Vlachopoulos et al. (2023) posit that educators propose strategies to address the environmental impact of digitalisation, such as prolonging device lifespans, responsible e-waste recycling, and promoting energy-efficient practices. Their findings highlight educators' concerns about energy consumption, carbon dioxide emissions, and electronic waste associated with digital technologies. Understanding educators' awareness and concerns regarding environmental sustainability aspects of digitalisation offers valuable insight for designing effective SDT strategies in HEIs. Educators emphasise the need for proper training in incorporating the environmental impact of digitalisation into the curriculum. Educators in HEIs underscore the importance of adequate training and support to integrate sustainability considerations into DT strategies (Moosa, Ncube and Ramnarain, 2023; Mesuwini and Mokoena, 2024).

A limitation of the study by Vlachopoulos et al. (2023) is exploring educators' perspectives on school education, not HEIs. The need for educator training on the environmental implications of digitalisation is relevant for faculty training in HEIs implementing sustainable digital practices. Higher education institutions share some concerns with K-12 schools about managing electronic waste and the energy consumption of digital infrastructure. Another good suggestion is that policymakers should consider environmental protection and economic development in an integrated manner to promote green digitalisation and environmental innovation amongst organisations, and

foster sustainable development (Lü, 2024). In addition, organisations should pay attention to environmental cooperation with supply chain partners, cultivate managers' environmental awareness, and focus on the role of interpersonal relationships in the cooperation. Organisations should also promote green digitalisation and environmental innovation more effectively, and enhance organisational competitiveness and environmental performance (Lü, 2024).

A foundational factor for SDT strategies in HEIs is analysing how stakeholders understand environmental sustainability and its relationship with digital technologies (Ajani and Dlomo, 2024). Ajani and Dlomo (2024) support HEIs in broadening their understanding of environmental sustainability beyond carbon-centric approaches when implementing SDT strategies. Despite the rapid growth of sustainability as a focal point, there remains a significant gap in effectively applying this knowledge to harness the potential of digital technologies (George et al., 2020; Muschert and Ragnedda, 2021; Guandalini, 2022; Feroz et al., 2023). There is a particular need for research on SDT strategies specific to HEIs, different from the broader trends in Industry 4.0 and Society 5.0 (Sá and Serpa, 2020; Machado et al., 2024). Similarly, the literature is limited on environmental management initiatives in HEIs, especially in regions lacking such initiatives (Pascual, 2023; Tshivhase and Bisschoff, 2023a). These broader trends, which encompass the impact of digitalisation on business practices, manufacturing, agriculture, and energy, highlight the interdisciplinary nature of many sustainability initiatives in HEIs (Dou et al., 2023; Wang and Mei, 2024).

Studies indicate that ICT infrastructure can contribute to sustainable development in different industries by promoting environmentally responsible practices (Moosa et al., 2023; Rivera-Gutiérrez et al., 2024).

2.3.3.1 Green digitalisation and environmental innovation

Green digitalisation and environmental innovation encourage organisations to recognise the importance of the environment and make them more environmentally friendly. At the same time, it can drive firms to be economically sustainable by reducing costs through reduced energy losses and raw material use (Sun et al., 2023; Vlachopoulos et al., 2023; Lü, 2024). In addition, firms that apply green digitalisation and environmental innovation are more socially responsible, and the positive effects of green innovations on society have been shown (Shahzad, Qu, Zafar, Rehman and Islam, 2020). Green digitalisation and environmental innovation are now widely recognised by stakeholders, including governments and consumers, as an important strategy for achieving sustainable development (Lü, 2024).

Guo, Geng, and Yao (2022) directly examine the link between green digitalisation and environmental innovation, a key aspect of SDT, and the impact of green digitalisation on environmental innovation within Chinese listed firms. Their study focuses on companies, offering valuable insights for HEIs to leverage in identifying and implementing relevant digital solutions. Higher education institutions are fundamental actors in environmental research. The study highlights the importance of research and development (R&D) investment in achieving environmental innovation and explores the moderating effect of institutional forces on green digitalisation. Guo et al. (2022) used a database of Chinese-listed companies and employed statistical analysis to examine the relationship between green digitalisation and environmental innovation. This approach offers valuable information, but the methodologies and data sources may not directly align with those typically used in HEI-focused studies.

The limitations of the firm-centric approach and the literature on digitalisation, R&D, and institutional forces remain relevant to HEIs' role in environmental innovation. While the literature provides general information on the relationship between digitalisation and environmental sustainability, future studies must address the specific context of HEIs, including their unique challenges and objectives. According to Guo et al. (2022), the DT of most Chinese firms is currently at an early stage. Therefore, the impact of DT on businesses' success in sustainable development deserves further exploration.

Green digitalisation and environmental innovation consist of various scopes, such as product and process innovation. When the type of environmental innovation varies, the impact on an organisation's sustainable performance also varies (Lü, 2024). The concept of green transformation aligns with HEIs' sustainability goals. The study by Guo and Zeng (2023) is highly relevant for HEIs that aim to reduce environmental impact and promote sustainability, as an example of DT for sustainable education practices, specifically focusing on online learning. Guo and Zeng (2023) discuss promoting green and low-carbon transformation in education, particularly in the context of online foreign language education. Promoting green and low-carbon transformation in education aligns with the broader theme of SDT (Shahzad et al., 2020). Guo and Zeng (2023) use the entropy weight method, multiple linear regression, and confirmatory factor analysis models to assess online satisfaction with foreign language teaching and identify critical influences. These methodological approaches provide a systematic framework for analysing the effectiveness of online teaching strategies, thereby informing DT initiatives in higher education. The study's findings indicate high satisfaction with online foreign language teaching among HEI students and identify critical dimensions influencing satisfaction.

Similarly, Sharma, Vaidya, and Deepika (2022) highlight student satisfaction as a key factor in evaluating the effectiveness of DT strategies. Understanding these factors is fundamental to designing effective SDT strategies in HEIs, particularly online language education programs. The study concludes by proposing specific strategies to enhance the effectiveness of green, low-carbon digital technology in foreign language education. These recommendations offer practical information for HEIs seeking to improve their online teaching practices while advancing sustainability goals. The study's narrow focus targets online foreign language learning and student satisfaction. The study needs to directly address the broader aspects of sustainability within HEIs (environmental, social, and economic).

While focused on businesses, Raman, Sreenivasan, Ma, Patwardhan, and Nedungadi (2023) highlight the growing importance of green supply chain management (GSCM) practices that contribute to the SDGs. Green Supply Chain Management is closely related to sustainable practices and DT (Raman et al., 2023). The Raman et al. (2023) study also mentions the role of DT in these efforts. Higher education institutions can explore how the principles of GSCM and digital solutions can be adapted to their operations to achieve sustainability goals. They employed SDG-mapping algorithms to connect GSCM research directly to the 17 SDGs. The study provides a comprehensive understanding of how GSCM practices contribute to achieving specific sustainability goals outlined by the United Nations. Through demonstrations, GSCM research directly addresses global challenges identified by the United Nations, providing policymakers and stakeholders in HEIs with valuable information. It highlights the importance of integrating sustainability into supply chain processes and utilising digital technologies to support environmental objectives. Raman et al. (2023) identify thematic areas in GSCM research, including Industry 4.0, sustainable sourcing, supply chain resilience, and DT. These areas are highly relevant for HEIs seeking to implement SDT strategies. There is evidence of international interest and collaboration in GSCM research across diverse regions, including Europe, Western countries, the Middle East, Southeast Asia, and Eastern Europe. Other critical areas, such as Africa and Latin America, are not explicitly included in the study, which implies an incomplete global perspective. The international perspective informs HEIs on best practices and emerging sustainable supply chain management.

A global study by Miglionico (2022) explores the use of digital technologies for climate risk management and sustainability reporting in financial institutions. While not directly focused on HEIs, it highlights the potential of digital tools to support sustainability goals. However, Miglionico (2022) underscores the importance of data standardisation and transparency in sustainability reporting, aligning with best practices for data-driven decision-making in SDT (Meijer, 2024). Understanding how to use digital technologies to address sustainability challenges and improve decision-making

processes can inform strategic planning in HEIs. However, HEIs have different reporting requirements and goals, and this research explicitly targets financial institutions and their regulatory environment. The focus indirectly addresses higher education, offering insights into how digital technologies improve data management and transparency for sustainability reporting. These concepts are generally applicable to any organisation, including HEIs. Miglionico (2022) further highlights two critical issues - sustainable finance and climate change - which are increasingly fundamental in HEIs' strategic agendas.

Many HEIs focus on sustainability initiatives and integrate climate change considerations into their operations (Strielkowski et al., 2022; Tshivhase and Bisschoff, 2023b). This topic is highly relevant, as DT strategies are integral to achieving sustainability goals in various sectors, including higher education. The present study discusses the role of digital technologies, particularly in addressing climate risk management and improving transparency in regulatory reporting for financial institutions. The present study explores innovative approaches, such as automated language systems, to enhance climate risk management and transparency. Higher education institutions can benefit from learning about best practices and emerging technologies in sustainability-related fields.

Tshivhase and Bisschoff (2023b), who directly address the challenges faced by HEIs in implementing sustainable practices, highlight the importance of environmentally friendly practices and the pressure in South African HEIs, particularly state-funded ones, to improve environmental management efficiency and awareness. Their study developed and empirically tested a model to measure the implementation of green initiatives (a form of sustainability) in HEIs. The model includes factors such as the cost of green products, the attitude and commitment of top management, the committee for sustainable accountability, and, notably, the DT. Tshivhase and Bisschoff (2023b) identify DT as a critical factor, yet do not elaborate on specific SDT strategies. While the scholars highlight the relevance of digital strategies in promoting sustainability within HEIs, they identify DT as one of the factors in the model for implementing green initiatives. Tshivhase and Bisschoff (2023b) employ structural equation modelling to validate the proposed model, providing empirical evidence of its validity and applicability. This methodological rigour enhances the credibility of the findings and their potential relevance to other HEIs. The conceptual model developed offers practical implications for South African state-funded HEIs to measure the implementation of green initiatives. The conceptual model informs the policy direction and strategic planning of these institutions, contributing to their achievement of the SDGs (Tshivhase and Bisschoff, 2023a).

Environmental sustainability contributes to the improvement of sustainable development performance by meeting environmental regulations and increasing social consensus (Sun et al., 2023;

Lü, 2024). At the same time, environmental sustainability helps create a green image and build relationships, further promoting sustainable development. Through environmental sustainability efforts, organisations can break down information barriers, gather and integrate environmental knowledge and technological resources, and enhance their environmental innovation capabilities. These efforts help in reducing pollution and improving environmental social responsibility performance while realising economic benefits (Sun et al., 2023; Lü, 2024).

HEIs are critical players in both Information Systems research and the implementation of SDT. The goals of SDT strategies include minimising environmental harm while leveraging digital technologies for positive social impact. Kranz et al. (2022) address the disconnect between knowledge of IS's potential to enable environmental sustainability and actual practices in academia, including research and teaching. Since HEIs are critical players in the drive of SDT, understanding and addressing such discrepancies is foundational. According to Kranz et al. (2022), digital technologies are studied without sufficiently acknowledging the significant amounts of resources they consume. Kranz et al. (2022) identify several challenges pertinent to discussions on SDT strategies in higher education. These challenges are present in current academic practices related to environmental sustainability, including excessive travel, resource-intensive research on digital technologies, and inadequate coverage of environmental considerations in teaching curricula. Kranz et al. (2022) raise the question of whether academia is practising enough of what it preaches regarding environmental sustainability. Furthermore, it calls for action and highlights the urgency of addressing the environmental impact of academic practices. Kranz et al. (2022) incorporate insights and perspectives from multiple experts from North America, Europe, and Asia, adding credibility and depth to the discussion. Kranz et al. (2022) propose three solutions to evolve current IS academic practices, including leveraging virtualisation and limiting air travel, overhauling teaching curricula, and recalibrating incentives and evaluation regimes. These ideas present practical strategies for integrating environmental sustainability into academic practices, forming the development and implementation of SDT strategies in HEIs. They emphasise the need for consistency between advocating for sustainability through IS solutions and unsustainable research practices.

Samuel et al. (2022) offer a critical consideration for the present study on SDT in HEIs. The scholars directly highlight the environmental impact of digital technologies by exploring expert perceptions of environmental sustainability. Samuel et al. (2022) posit that the energy consumption required to generate and process large amounts of data through digital technologies contributes significantly to carbon dioxide emissions. These emissions are linked to the energy demands of data generation and processing, the extraction of minerals for manufacturing technological components, and the resulting e-waste. Furthermore, the scholars examine stakeholders' conceptual understanding of sustainability

and its relationship to the environmental impacts of digital technologies. Samuel et al. (2022) present stakeholders' conceptual understanding of sustainability as a universally accepted value, yet it is also an abstract concept difficult to define and measure. However, their study does not exclusively focus on HEIs, yet the findings are generally applicable. Consequently, the following section explores the leveraging of digital technologies to examine industry practices.

2.3.3.2 Leveraging digital technologies for sustainability in HEIs: Insights from Industry Practices

Beier et al. (2022) explore the potential of Industry 4.0 for environmental sustainability in industry, highlighting the importance of supporting measures to achieve this goal. Similarly, HEIs implementing SDT strategies may benefit from similar considerations. A critical evaluation is necessary to ensure these strategies contribute to broader sustainability objectives. Beier et al. (2022) examined the impact of digital technologies on environmental sustainability in industrial sectors in Brazil, China, and Germany. The findings offer valuable information for HEIs in formulating DT strategies focusing on environmental sustainability. The study explored the potential of Industry 4.0 for environmental sustainability in industrial production, highlighting the importance of supporting measures to achieve this goal, given the limited empirical evidence on Industry 4.0's impacts on corporate environmental sustainability. Beier et al. (2022) help address this gap by investigating practice expectations and experiences, concluding that several critical factors covered in the study are vital to improving environmental sustainability in industrial production through Industry 4.0 technologies.

As HEIs increasingly adopt digital technologies for governance and administration, understanding the potential environmental costs and barriers to sustainability is essential. In addition, Meijer (2024) examines the relationship between e-Governance and sustainable development, which is highly relevant to understanding SDT strategies across sectors, including higher education. The study addresses the intertwined nature of digitalisation and sustainability (twin transition) and the potential adverse environmental aspects of e-Governance. This understanding is foundational for addressing the environmental costs associated with e-Governance. The study aligns with the core theme of sustainable DT within HEIs. Meijer (2024) provides a conceptual analysis that extends beyond the conventional focus on the positive aspects of e-Governance for sustainable development. Through examining the potential environmental costs and institutional perspectives on e-Governance, the study offers a more nuanced understanding of the complex relationship between digitalisation and sustainability. Meijer (2024) highlights the importance of examining the destructive connections between technology and environmental sustainability. Calling for a broader analysis that includes the environmental costs of e-government services. The scholar stresses the need to expand the focus

beyond the instrumental use of technology to include fundamental ontological and normative foundations. This shift is essential for understanding transformational change in society and the role of e-Governance in sustainable development. Meijer (2024) identifies three critical issues for further research: green e-Governance, e-Governance as a barrier to the sustainability transition, and the ecological logic shaping the twin transition. Meijer (2024) concludes with a research agenda highlighting the importance of profoundly studying these critical issues. While HEIs use digital tools for administration, such as AI, Big Data, IoT, Cloud computing, or Blockchain, their specific context and challenges differ from those of broader governance structures. Through providing a roadmap for future research, the study contributes to advancing knowledge and understanding in this area, essential for forming evidence-based decision-making in HEIs (Meijer, 2024). These issues collectively underscore the complexity of the twin transition and the necessity for a more integrated approach to e-Governance and sustainability. The study's results provide valuable information for researchers and policymakers seeking to develop effective SDT strategies to promote sustainability in HEIs.

Of interest for SDT strategies in HEIs is the study on environmentally sustainable educational technology. Mentioning both schools and HEIs, Selwyn (2021) directly addresses sustainable educational technologies, aligning with the focus on sustainable strategies. Selwyn (2021) critiques the uncritical adoption of digital technologies in education and highlights the importance of environmental considerations. The study focuses on displaced populations, which is relevant to the broader resource limitations and environmental impact considerations. Sustainable educational technology (EdTech) solutions are envisioned as transformative approaches that address both educational needs and environmental concerns (Obesso, Núñez-Canal and Pérez-Rivero, 2023). In addition, the broader societal implications mention the study's consideration of displaced populations as a potential future challenge for HEIs to address through sustainable EdTech solutions. Selwyn (2021) provides a critical perspective on SDT in HEIs, highlighting important considerations for developing sustainable EdTech strategies, critiquing business-as-usual approaches to educational technology, and the need for environmentally conscious strategies. Selwyn (2021) emphasises that the environmental impacts of educational technology are often overlooked. Arguing that continuing with current forms of EdTech strategies without considering these impacts is not sustainable. The study considers resource limitations and environmental impact as HEIs develop SDT plans. Selwyn (2021) advocates a sustainable approach to educational technology, involving co-evolving and co-creating solutions that benefit both humanity and the environment, to address how HEIs can minimise the environmental footprint of their technologies.

A study by Vandevenne et al. (2023) directly addresses the intersection of DT and environmental sustainability (ES) in organisations. The scholars highlight a significant knowledge gap in integrating environmental sustainability into DT initiatives and propose a green enterprise architecture (GREAN) framework to bridge this gap. Moreover, the scholars emphasise the environmental implications of DT and the importance of adopting sustainable strategies to mitigate them. Vandevenne et al. (2023) make a significant contribution to the SDT strategies landscape by developing an artefact that provides a comprehensive framework for embedding environmental sustainability across multiple organisational layers. The GREAN framework encompasses strategy, business, data, application, and technology layers, serving as a foundational tool for organisations aiming to effectively integrate sustainability into their DT initiatives. Vandevenne et al. (2023) use a design science research approach and systematic literature review to validate findings, demonstrating a robust research methodology. Although the study effectively outlines a theoretical framework and methodology for SDT, its primary focus lies outside the HEIs. However, the core concept of GREAN is adaptable to the higher education context. Higher education institutions can adapt courses of action (CoA) across various organisational functions to meet specific institutional requirements. Vandevenne et al. (2023) suggest the need for further investigation into the application of GREAN within the higher education sector. The findings and frameworks presented can guide HEIs in embedding sustainability into their DT efforts, ultimately contributing to a more sustainable future.

Higher education institutions are increasingly concerned about their environmental footprint and are looking for ways to integrate digital technologies to promote sustainability in various domains (Selwyn, 2021; Strielkowski et al., 2022). Truong (2022) discusses both the opportunities and challenges associated with DT in the environmental sustainability domain. Understanding these opportunities and challenges is foundational for HEIs as the institutions navigate the complexities of integrating digital technologies into sustainability initiatives. Truong (2022) presents a comprehensive analysis of the complexities and nuances of employing digital technologies for sustainability initiatives. The study emphasises transformative actions that safeguard the environment in critical areas, including waste management, pollution reduction, and sustainable resource usage. It identifies specific ways in which digital technologies contribute to environmental sustainability efforts. These insights can assist higher education institutions in designing targeted SDT strategies to effectively address environmental challenges (Meijer, 2024). Truong (2022) reviewed various digital solutions that could transform the environment. The four main themes of digital technologies examined include AI, Big Data, IoT, Cloud computing, and Blockchain. Of the 106 articles selected from 2011 to June 2021 for technical review, AI applications were utilised in 44 papers, followed by Big Data analytics with 13 papers; Blockchain was leveraged in 11 papers, the same as for IoT. In

summary, pollution prevention and control are the areas with a slightly higher number of research regarding digital disruptions, followed by waste management and handling and sustainable resource management. Vlachopoulos et al. (2023) posit that HEIs may use digital technologies to improve environmental sustainability in their operations, for example, waste management systems and energy-efficient buildings.

A study by Lee and Kim (2020) aimed to understand how mobile operators leverage digital technologies for sustainability, for example, addressing climate change. While Lee and Kim (2020) focus directly on mobile operators, they offer valuable insights for HEIs with similar sustainability goals. The scholars' investigation into the use of AI, IoT, and Big Data in Korea Telecom's (KT) operations highlights the transformative potential of these technologies for institutional sustainability. Lee and Kim (2020) discussed how a mobile operator, KT, expanded its business beyond traditional communications or media to smart energy services using digital technology.

This present case study provides valuable insights into how institutions can leverage DT to diversify their offerings and address sustainability challenges. The present study identified critical factors that contributed to the success of the KT case. The study emphasises the importance of adapting insights to suit the unique contexts of educational institutions. Understanding how digital technologies are able to contribute to sustainability initiatives is essential for HEIs seeking to integrate sustainable practices into their operations and curriculum. However, caution is necessary when generalising findings to ensure relevance and applicability to the HEI context.

Specific aspects of DT, such as digital products, operations, and talent, have the most significant impact and are valuable for understanding effective strategies for HEIs (Hu, Lin, Feng, and Yi, 2023). These insights can inform HEIs about which aspects of DT to prioritise for maximum impact. The study focuses on Chinese organisations; the findings on successful strategies generally apply to HEIs worldwide. Hu et al. (2023) offer an example of exploring the performance benefits of DT for sustainability-oriented companies. Furthermore, the study provides empirical evidence of DT's positive impact on firm performance. Understanding the performance implications of DT is fundamental for HEIs that want to assess the effectiveness of their own DT strategies.

Hu et al. (2023) highlight the mediating effect of DT on green technology innovation, suggesting a pathway through which DT can indirectly contribute to performance improvement. This understanding can guide HEIs in harnessing DT to promote innovation in sustainable practices. For HEIs with diverse structures and missions, the present study examines how DT's impact differs between state-owned and private enterprises. This nuanced analysis offers insights into how different organisational contexts may influence the effectiveness of DT strategies.

The following section examines the use of digital technologies to drive DT in higher education, alongside aspects of competitive advantage, dynamic capabilities, and decision-making.

2.4 Digital transformation strategies

This section delves into the key components, frameworks, and best practices associated with DT strategies in HEIs, emphasising their role in shaping the future of education.

2.4.1 Integration of digital tools

Another intervention is the provision of sustained improvement in the effective use of technological tools and their integration into teaching practice by educators (Chanias et al., 2019; Di Vaio et al., 2021). The current literature recognises the exponential advance of AI and ML (Çınar et al., 2020; Samuel et al., 2022; Abulibdeh et al., 2024). Both businesses and governments strive to maximise the potential of technological tools, though the objectives differ significantly: businesses primarily aim to generate profit, while governments focus on public service and social welfare (Hanelt, Bohnsack, Marz and Antunes Marante, 2020).

A recent systematic literature review by Abulibdeh et al. (2024) of 134 peer-reviewed articles from various sources identified through searches in Web of Science, Scopus, and Google Scholar showed that HEIs must adapt to the evolving job market and sustainability demands in Industry 4.0. Most of the 134 articles were published recently, indicating a surge in relevant research. Abulibdeh et al. (2024) mention integrating advanced technologies, such as AI, into education, specifically highlighting the potential of AI chatbots, such as ChatGPT, to revolutionise learning experiences. Adaptive learning systems use algorithms to adjust the pace and path of learning based on an individual student's performance. The learning systems are using AI-powered platforms to create personalised learning experiences, a relevant aspect of understanding how HEIs adopt SDT strategies to improve teaching and learning processes. Abulibdeh et al. (2024) highlight ethical concerns associated with integrating AI into education, a significant consideration when evaluating the effectiveness of SDT strategies in higher education. Abulibdeh et al. (2024) critique traditional approaches to educational technology and advocate for strategies that prioritise environmental consciousness. It suggests that education for sustainable development (ESD) promotes responsibility and proactive participation in sustainability.

Education for sustainable development, as reported by Strielkowski et al. (2022), aims to enhance knowledge and behaviours for environmental care. It also promotes social justice, economic sustainability, and environmental protection. Abulibdeh et al. (2024) further note that continuous learning strategies in education are lacking, despite the need for lifelong learning. Sustainability in

education extends beyond environmental practices to include the cultivation of lifelong learning skills essential for adapting to a rapidly changing world. Despite the recognised need for lifelong learning, many educational systems lack robust strategies to embed continuous learning into their frameworks.

Rooein et al. (2022) studied the use of chatbots for adaptive learning of business processes, explicitly targeting business process education. While focusing on business training, adaptive learning platforms are indirectly relevant to HEIs looking to personalise learning experiences through DT. The study highlights the importance of user-centred design and adaptability in learning technologies, which aligns with best practices for educational technology in HEIs. Business process education is required for training in the context of the core curriculum delivery in HEIs. The aCHAT-WF framework (adaptive CHATbot for WorkFlows), as proposed, manages conversational interfaces that conceptually embody many features related to conversations about business processes, with different facets for users. The related features include conversation flow and the conversation contents, merging them to achieve a flexible interaction with the user. The maintainability of the aCHAT-WF framework itself contributes to the technical sustainability aspect. While important, it is not directly equivalent to sustainability in a broader sense. Sustainability also encompasses environmental impact and social equity (Jekabsone and Gudele, 2023). While chatbot technology offers potential benefits, challenges remain. User acceptance can vary, with some individuals finding chatbots intrusive or overly talkative (Rooein et al., 2022). Additionally, equitable access to chatbot-based learning solutions can be hindered by factors such as Internet connectivity and device availability.

In 2020, Çinar et al. (2020) studied the application of ML techniques in predictive maintenance (PdM) for smart manufacturing in the context of Industry 4.0. The review paper provides insight into cutting-edge technologies HEIs may consider adopting as part of their SDT strategies. Understanding these advances helps inform decisions related to technology integration in HEIs. Institutions in engineering, technology, and applied sciences could leverage similar ML techniques for predictive maintenance of equipment and facilities, contributing to sustainability efforts by improving resource use and reducing downtime. Unlike HEIs, the study targets the industrial manufacturing sector, yet HEIs can educate the future workforce about Industry 4.0 and its technologies.

Understanding the perception of cybersecurity threats is fundamental for developing effective strategies to mitigate risks and improve cybersecurity resilience. Cybersecurity becomes critical as HEIs increasingly rely on digital technologies for teaching, research, and administrative processes. Cybersecurity in HEIs is critical because these institutions store sensitive data, facilitate online collaboration, and are attractive targets for cyberattacks. The findings of the present study can inform

policy decisions and educational programs aimed at promoting cybersecurity awareness and preparedness in HEIs.

Gombár, Vagaská, Korauš, and Račková (2024) focus on cybersecurity and risk perception in the context of Industry 4.0, not the broader concept of SDT strategies. Gombár et al. (2024) contribute to the literature by developing a factor model of cybersecurity threat risk perception and providing a framework for further research and practical applications in cybersecurity management. Gombár et al. (2024) explore cybersecurity in the context of Industry 4.0. The study focuses on the perception of cybersecurity threats. Through mathematical modelling, specifically structural equation modelling (SEM) and confirmatory factor analysis (CFA), a factor model of cybersecurity threat risk perception is developed. This methodological rigour enhances the credibility of the study findings.

Gombár et al. (2024) employed quantitative analysis techniques to assess respondents' perceptions of cybersecurity threats, particularly students at HEIs in the Slovak Republic and the Czech Republic. Expanding the sample to include faculty, administrators, and international populations could provide a more holistic view of risk perception. Validation of the research instrument ensures the reliability and validity of the findings. However, while Gombár et al. (2024) provide a robust analysis of cybersecurity perceptions, their focus on Industry 4.0 may limit the applicability of their findings to other contexts within HEIs. Understanding how digital technologies can contribute to both cybersecurity resilience and sustainability is foundational for HEIs as they navigate an increasingly complex digital landscape. In this regard, integrating insights from studies such as Agrawal et al. (2023), which explore the intersection of circular economy practices and disruptive digital technologies, can inform HEIs' approaches to both sustainability and cybersecurity. The identification of drivers, barriers, and enablers in Agrawal et al.'s (2023) framework can be adapted to understand how HEIs can effectively manage cybersecurity risks while promoting sustainable practices.

2.4.2 Competitive advantage and dynamic capabilities

Endres, Helm, and Dowling (2020) discuss the importance of understanding the drivers of continuous change and renewal in today's digital world, emphasising the need to achieve sustainable competitiveness. The study highlights the need for companies to develop capabilities that detect market opportunities and threats, aligning with the DT goals in HEIs. Higher education institutions can gain insight into how to sustainably position themselves in the digital landscape by understanding the determinants of sensing capability and their impact on revenue growth. Endres et al. (2020) offer practical perceptions for industrial managers (marketing) on effectively using various sources of market knowledge to sense market opportunities and threats. Higher education institution managers

can adapt and apply these insights to improve DT strategies and their competitive positioning. Top managers at internationally operating industrial firms provided survey data to test hypotheses, which researchers complemented with objective data on revenue growth. This empirical approach adds credibility to the findings.

Using data analytics to track student progress, identify at-risk students, and personalise learning experiences is a growing trend (Hampton and Foley, 2022; Naveed, Qahmash, Al-Razgan, Qureshi and Alwan, 2022; Tibatshi and Ramafi, 2023). Learning analytics enables institutions to make data-driven decisions that improve educational outcomes. Higher education institutions are increasingly relying on digital technologies to enhance their operations, teaching methods, and research capabilities. Lichtenthaler (2020) examines the use of data analytics and AI as tools to achieve a sustainable competitive advantage. Lichtenthaler (2020) focuses on a business context and highlights the importance of integrating these technologies with human expertise. Higher education institutions implementing SDT strategies may consider data analytics and AI as potential tools, recognising the need to integrate them with educators' expertise. Lichtenthaler (2020) presents a best-practice case study of Liverpool Football Club, demonstrating how integrating data analytics, AI, and human expertise contributed to the club's revival in both sporting success and financial performance. While the context is sports management, the principles and lessons learned can be applied to various industries, including higher education. Lichtenthaler (2020) offers conceptual arguments and managerial insights on how corporations can leverage data analytics and AI to achieve sustainable competitive advantages. These insights can be valuable to decision-makers in HEIs seeking to improve their competitiveness through SDT strategies, as they prioritise human-centred learning and teaching methods alongside technological advancements (Joseph, Onwuzulike and Shitu, 2024). The case study emphasises integrating human intelligence and expertise with AI solutions to maximise their impact and sustainability. This integrated intelligence approach aligns with the evolving role of technology in higher education. Furthermore, the case study provides new theoretical insights and practical implications, contributing to a deeper understanding of how corporations effectively profit from AI and data analytics.

Understanding the implications of Industry 4.0 on sustainability can provide insight into similar strategies in HEIs. Dynamic capabilities are a foundational factor for successful SDT strategies. Felsberger, Qaiser, Choudhary, and Reiner's (2022) study proposes a framework to investigate the impact of Industry 4.0, particularly DT, on sustainability dimensions in European manufacturing industries. The study proposes an evaluation framework to identify the implications of Industry 4.0 in achieving sustainable competitive advantage. The evaluation framework could be adapted or extended to assess the effectiveness of SDT strategies in HEIs in promoting sustainability. The study

examined six European manufacturing companies across aerospace manufacturing and the production of electronic components and systems, providing empirical evidence on the impact of Industry 4.0 on sustainability dimensions. Presenting theoretical propositions that reveal the interrelations between Industry 4.0, the dynamic capabilities of the firm, and the sustainability dimensions. These propositions serve as a basis for developing hypotheses or research questions related to SDT strategies in HEIs. Higher education institutions face constant changes in technology, student expectations, and regulatory environments. Dynamic capabilities enable these institutions to adapt their curricula, teaching methods, and administrative processes to meet new demands and challenges. Similar to firms focusing on sustainable competitive advantage, HEIs can apply dynamic capabilities to enhance their social responsibility initiatives. Applying dynamic capabilities can include developing programs that address societal challenges, promoting sustainability in campus operations, and engaging with local communities. Higher education institutions can develop these dynamic capabilities to adapt to new technologies and implement them for sustainable practices, such as online learning, reducing commuting emissions, or implementing energy-efficient buildings.

HEIs also strive to align their digital initiatives with sustainability goals. Feroz et al. (2023) used mixed methods, including a literature review, qualitative meta-synthesis, a survey questionnaire, and a modified Delphi method to develop a robust SDT framework and identify dynamic capabilities for SDT. This comprehensive approach improves the credibility and reliability of the findings, making them applicable to the educational context. Hess et al. (2016) proposed studying how dynamic capabilities contribute to DT. This SDT framework delineates SDT as a reconfiguration process that aligns digital technologies with sustainability goals, providing a structured approach for institutions, including HEIs embarking on SDT journeys. The dynamic capabilities identified in the study offer practical insight for institutions. The study contributes theoretical insights that inform future research in both fields by proposing an SDT framework and identifying dynamic capabilities. The study addresses a significant literature gap by exploring the intersection of DT and environmental sustainability.

Mohammadian, Vares, Hajiheydari, Khajeheian and Shouraki (2021) analysed the interaction of critical factors of Sustainable Business Model Innovation in the Digital Age based on dynamic capabilities. The study used an integrative meta-synthesis and interpretive structural modelling (ISM) approach. As HEIs increasingly embrace DT to improve sustainability, understanding business innovation models in this context is highly relevant. The study employed a mixed-methods approach, combining qualitative meta-synthesis (a systematic review of 402 related articles, with 46 selected for in-depth analysis) with quantitative ISM. The comprehensive approach enabled a deeper understanding of the complex relationships between dynamic capabilities, sustainable business model

innovation, and dynamic capabilities. Through thematic analysis of previous research articles, the study identified critical factors that influence the innovation of sustainable business models. The subsequent development of an ISM provides a visual representation of the interrelationships between these factors, offering valuable insights for both academic and industry practitioners. The study proposes an 8-level hierarchy model of factors influencing the innovation of sustainable business models, demonstrating a structured approach to understanding the complexity of DT and sustainability.

In their study Mohammadian (2021) used the MICMAC (Cross-Impact Matrix Multiplication Applied to Classification) approach, derived from the French Matrice d'impacts croisés multiplication appliquée à un classment. The MICMAC approach helps categorise factors based on their driving power and dependence, further enhancing the depth of analysis. The MICMAC matrix includes a diagram in which the vertical axis represents the driving power, and the horizontal axis represents the dependence of a variable (Mohammadian et al., 2021). The study findings, which include identifying factors such as digital technologies, network value, sensing, and economic sustainability, have practical implications for institutions seeking to sustainably innovate their business models in the digital age. Higher education institutions can benefit from understanding these factors and their interrelationships to inform their DT strategies.

A study from the United Arab Emirates that explicitly examines how DT creates competitive advantages for HEIs aligns well with the broader focus on the role of DT in HEIs (Mohamed Hashim et al., 2022b). The study explores sustainable education management within an environmental and social sustainability context and the critical aspects of DT in HEIs. The focus is on developing a qualitative model, which may offer fewer practical implementation strategies than studies directly evaluating effectiveness. The study provides empirical insights into the impactful changes affecting HEIs' vision and explains how these changes can be transformed into advantages through DT strategies. Furthermore, it develops a qualitative model advocating the use of DT to build competitive advantages in HEIs. This approach provides valuable information on the mechanisms and strategies for implementing DT initiatives in HEIs. The study recommends developing and implementing strategies that leverage DT to create competitive advantages by enhancing the student experience, meeting evolving expectations, and using globalisation, information exchange, digitisation, and social media. The study also suggests integrating evolutionary learning mechanisms to continuously adapt and improve HEI strategies.

Understanding the intellectual roots, research fronts, trends, and gaps in Industry 4.0 research can inform the development and implementation of SDT strategies in various sectors, including higher

education. Machado et al. (2024) focused their study on Industry 4.0 and its effects on sustainability. Industry 4.0 encompasses a wide range of industries; the study focuses on using a bibliometric approach to analyse a large set of Industry 4.0 publications. While it offers insight into research trends, it does not directly assess the effectiveness of specific strategies. Industry 4.0 is highly relevant for DT strategies, including those in higher education. Machado et al. (2024) propose a bibliometric review of the Industry 4.0 research field to identify its intellectual roots, research fronts, trends, and gaps. The approach provides a systematic and comprehensive analysis of the existing literature, offering valuable insights to researchers and practitioners interested in SDT. Through providing these insights into the intellectual structure, research fronts, and thematic evolution trends of the Industry 4.0 research field, the present study informs future research directions and priorities, including those related to SDT in HEIs. The study identifies two general topics related to Industry 4.0: the implementation of Industry 4.0 and its impact on sustainability. Understanding these research fronts and trends helps HEIs align their DT strategies with sustainability goals and address emerging challenges and opportunities in the field. Machado et al. (2024) claim novelty by proposing a bibliometric review that includes all documents in the WOS and SCOPUS core collections related to Industry 4.0. This comprehensive approach ensures that the review captures a wide range of research themes, trends, and gaps in the Industry 4.0 literature, enhancing its relevance and completeness.

Masmali and Miah (2023) from the Kingdom of Saudi Arabia discuss the impact of Industry 4.0 on HEIs, highlighting the need for HEIs to adapt their programs, facilities, and infrastructure to align with the requirements of Industry 4.0. Through a systematic approach, including questionnaires, SWOT analysis, and the analytic hierarchy process (AHP), to explore and analyse the factors influencing the progression of Industry 4.0 in HEIs. This systematic methodology provides a structured framework to assess the effectiveness of DT strategies in HEI. Incorporating stakeholder perspectives is essential for understanding the implementation and impact of DT strategies in HEIs. Masmali and Miah (2023) mention administering questionnaires to HEI employees and students to assess their viewpoints on Industry 4.0 in higher education. Additionally, establishing a SWOT matrix to identify strategic schemes for HEIs in response to Industry 4.0. Identifying strategic schemes based on strengths, weaknesses, opportunities, and threats informs the development of SDT strategies in HEIs.

In alignment with the goals of the SDT strategies in HEIs, Masmali and Miah (2023) emphasise the importance of practical expertise and the implementation of digital technologies at the HEI level to empower students with the required skills for Industry 4.0. The research findings include Modernising HEI facilities to support the technological demands of Industry 4.0. Updating educational programs to include relevant skills and knowledge for Industry 4.0, enhancing collaboration with industries to

provide practical experience and training, and integrating digital tools and technologies into the educational environment to foster a competitive edge for students.

2.4.3 Data-driven decision-making

Higher education institutions are critical stakeholders in pursuing sustainability goals, and understanding how DT can support localisation efforts informs strategies within HEIs. According to ElMassah and Mohieldin (2019), effective planning and budgetary allocations at the local level are significant and can apply to HEIs in their strategic planning processes. Localising the SDGs involves adapting strategies to local contexts for effective implementation. Additionally, the emphasis on data-driven decision-making and digital technologies resonates with initiatives to improve efficiency and sustainability within HEIs. Their study is directed at national governments, not explicitly HEIs.

ElMassah and Mohieldin (2019) explore how DT can support the localisation of the SDGs. Granting that it focuses on national governments, the research provides valuable insights into the importance of considering local contexts during DT initiatives. Higher education institutions can use data analysis to tailor their digital strategies for practical sustainability efforts. Higher education institutions can contribute by educating students on data analytics, digital governance, and sustainable practices, thus preparing a workforce capable of driving DT in various sectors. Aligning with the broader goal of fostering a knowledgeable society that can address sustainability challenges.

Bokolo (2023) provides an example of effective DT strategies that foster innovation and improve services through data-driven decision-making. The discussion of principles and methodologies offers practical insights and real-life evidence to define data-driven enablers in smart cities, which can guide similar initiatives in HEIs. Following a qualitative evaluation of the developed architecture, the design science research focused on data-driven approaches to urban data management, aiming to improve smart city planning and design. Universities and colleges increasingly rely on data-driven strategies for decision-making, resource allocation, and improving services for students and faculty. Bokolo (2023) provides insights into data governance, which is essential for HEIs as they navigate the complexities of DT. Implementing robust data governance frameworks can help HEIs manage data security, privacy, and quality, ensuring that their digital initiatives are sustainable and effective.

Higher education institutions are increasingly integrating digital technologies into their operations and strategies, including corporate social responsibility (CSR) and sustainability efforts. Understanding how DT affects CSR performance in corporate settings provides valuable information for HEIs looking to enhance their own CSR initiatives through digital means. Sun et al. (2024) touch on sustainability through CSR performance, as it incorporates environmental considerations. The study integrates green management innovation into the digitalisation-CSR framework. It further

focuses on the impact of DT on CSR performance, noting that Chinese corporates show low overall CSR scores, indicating room for improvement. The study identifies mechanisms, including improving green management innovation and increasing analyst coverage through DT, that have parallels in the context of HEIs and can impact CSR performance. For example, DT in HEIs leads to innovations in sustainability practices, increased transparency and accountability, and improved stakeholder participation, all of which contribute to improved CSR performance. The study findings on the differential impact of DT on CSR performance, based on resource endowments and institutional environments, inform strategic decision-making. Higher education institutions with varying resource levels and operating in different institutional contexts can tailor their DT strategies to maximise positive effects on CSR performance, thereby contributing to the SDGs. The practical guidance provided by Sun et al. (2024) on promoting corporate social responsibility and achieving SDGs in the digital age is also relevant to HEIs and their stakeholders. Higher education institutions are critical stakeholders in broader societal sustainability efforts, and insights from corporate contexts may inform their approaches to social responsibility and sustainability efforts.

Higher education institutions are increasingly adopting digital strategies, and understanding how efficient data management drives innovation and value creation is foundational. Lichtenthaler (2022) addresses the role of data management efficiency in DT, noting that many organisations have been slow to recognise its importance, often focusing instead on data management effectiveness. The study emphasises the connection between data management efficiency and innovation-driven value creation. This perspective aligns with the SDT objectives in higher education, where innovation is essential to improve educational outcomes and operational efficiency. Furthermore, Lichtenthaler (2022) highlights a gap in the literature on neglecting data management efficiency in digitalisation efforts. Although the goals and challenges of HEIs differ from those of businesses, addressing this gap contributes valuable insights to the broader discussion of SDT strategies, including those relevant to higher education. Lichtenthaler (2022) presents a process segmentation for implementing shared value innovations in digital efficiency. The “creating shared value framework” provides guidance for higher education institutions aiming to improve their digital capabilities and generate value for stakeholders. The “creating shared value framework” emphasises integrating economic, environmental, and social benefits, highlighting data management efficiency as a significant contributor to TBL.

Understanding how data management efficiency can create opportunities for entrepreneurs and innovators aligns with the goals of fostering innovation and entrepreneurship within HEIs. Lichtenthaler (2022) expands the research into entrepreneurial marketing and the innovation-based view of firm performance. The innovation-based view of firm performance serves as a conceptual

lens to analyse the dynamic transformation of business processes and the opportunities for shared value innovation. Data management efficiency is an essential aspect of DT across various sectors. Higher education institutions are advised to proactively address data management efficiency to benefit more than those that wait until they are forced to act due to external disruptions, such as the COVID-19 pandemic.

Analysis of a real-world scenario, such as Meorient's DT, provides valuable insights into practical strategies and potential pitfalls (Bai, Yang, Hunter and Wang, 2022). The study addresses the critical issue of DT, which is highly relevant for HEIs when navigating the digital landscape to improve teaching, learning, and administrative processes. The study presents a practical DT through the example of Meorient, a Chinese company facing challenges and opportunities in the digital era. Through examining Meorient's decision-making process regarding its digital platform strategy, HEI stakeholders can gain practical insights into the complexities and considerations involved in DT initiatives. Meorient launched "Webshow MAX," a comprehensive digital exhibition product that integrates various service modules, including digital exhibiting and buyer-exhibitor pairing.

The shift to a digital solution is fundamental to adapt to the challenges posed by the COVID-19 pandemic, which severely impacted offline exhibitions (Bai et al., 2022). Despite the growth in digital solutions, Meorient faced significant strategic risks. Meorient's operational performance indicates that while operating revenue increased, the company still faced challenges with profitability and strategic alignment in the digital exhibition space. Although Meorient facilitated better communication between buyers and sellers, leading to increased business exchanges. Similarly, HEIs can enhance student engagement and learning outcomes by using data analytics to personalise learning experiences, track student progress, and improve course offerings. There is uncertainty surrounding a critical decision for the company's survival and competitiveness in pursuing a purely digital platform strategy or integrating online and offline business models. Just as Meorient had to pivot towards digital solutions due to the COVID-19 pandemic, HEIs are also compelled to adapt their teaching and operational models in response to global disruptions. In addition, HEIs must also navigate similar strategic choices, such as balancing online and traditional learning methods. Institutions need to assess their unique contexts and resources to determine the most effective approach to DT.

Shenkoya and Kim (2023) highlight the limited research on DT in higher education and its impact on sustainability. The study offers empirical evidence of the positive effects of DT on developing sustainable curricula, enhancing innovation, and improving student performance within HEIs. The study specifically examines the impact of DT on higher education and its implications for

sustainability. It synthesises existing research through a systematic literature review and bibliometric analysis, providing valuable insights into the current state of knowledge on this topic. The methodology involves a systematic literature review and analysis of bibliometric data, ensuring a comprehensive and rigorous examination of the subject matter. The study highlights several critical findings related to SDT in higher education, including developing sustainable curricula, digitalising education, enhancing innovation, and improving student performance. These findings inform the development and implementation of effective SDT strategies in HEIs. The findings show that the future of the DT of the higher education sector was the advancement of the concept of 'Education 4.0'. This implies the use of the advanced technologies of the fourth industrial revolution within the higher education sector. In addition, the findings show that in the future, AI and AR will play a major role in reforming higher education worldwide. Due to more innovative approaches to learning, such as the use of the Bluetooth Beacon by students and faculty.

Biclesanu et al. (2023) compare the perspectives and decisions of first-year bachelor's and second-year master's students in Bucharest, offering insights highly relevant to HEIs with business-related programs. This comparative analysis explicitly focuses on modern digital technologies, including robotic process automation, big data, AI, and the IoT. This suggests implications for curriculum development in HEIs, such as the proportion of students unsure about how modern technologies could improve a company's innovation and performance. Biclesanu et al. (2023) suggest that as students advance in their studies, their readiness to engage with technology and entrepreneurial activities increases. Furthermore, the study offers insights into the uncertainty surrounding how modern technologies can enhance business innovation and performance. Indicating a gap in knowledge that needs to be addressed. A reliance on self-assessment from respondents, the consideration of only one variable per personality characteristic, and unequal sample sizes between the two cohorts studied are some of the limitations of the study (Biclesanu et al., 2023). Despite these limitations, the data show acceptable reliability and no outlier issues. Building on this, future research could benefit from longitudinal or experimental approaches to better understand the evolving relationship between technology preparedness. Collaborating with industry partners is also recommended to ensure that educational adaptations remain relevant and effective.

Slavinski, Todorović, and Obradović (2023) discuss how research themes in project management, including those related to DT, have evolved. Research on the challenges and complexities of implementing SDT strategies in HEIs is important. Studying project management is valuable for HEIs undertaking complex SDT initiatives. Understanding the evolution of research themes provides insight into how DT strategies have been studied and implemented in various contexts, including HEIs (Hanelt et al., 2020). Future trends in project management research, including challenges related

to the 4IR, DT, and SDGs (Slavinski et al., 2023). These future trends are highly relevant to HEIs as they navigate technological changes and strive to achieve sustainability goals. The findings of Slavinski et al. (2023) may help researchers and educators in HEIs define the thematic orientation of their studies and programs.

Understanding emerging research themes and trends can guide the development of curricula and research agendas related to SDT strategies. The study provides insights that inform the modelling of research design for future studies in project management and related fields. In understanding emerging research themes and trends, HEIs can better develop curricula and research agendas that align with SDT strategies. Researchers in HEIs can use this information to design studies that address emerging challenges and opportunities in DT. The study's methodology, involving critical word co-occurrence analysis, is applicable in bibliometric analyses within higher education to anticipate future research thematic orientations. Critical word co-occurrence analysis can directly support the identification of themes relevant to HEIs' SDT strategies. The approach helps researchers and institutions stay informed about emerging trends and priorities. However, the study analyses research themes in project management, a broader field not specific to HEIs. While DT is mentioned as a potential trend, the study does not explore established strategies, limiting its direct applicability to SDT in higher education.

2.5 Chapter summary

In brief, much of the current literature on SDT strategies highlights trends highly relevant to SDT strategies within HEIs. These critical topics include information technologies, DT, innovation, and sustainability. Sustainability is a fundamental area of focus for HEIs, and understanding the broader trends and implications of DT in this post-pandemic era can inform strategic decisions. This chapter argues that current educational frameworks may not sufficiently prepare students for the practical application of technology in the job market. The assertion advocates for HEIs to enhance their curricula by incorporating more hands-on, technology-focused coursework, projects, and industry involvement. To assist students in better understanding the relevance of technology in their future careers. This chapter points out that current education systems often reflect outdated industrial-era values and methods.

This chapter elucidates that understanding different levels of engagement and sustainability is foundational for developing effective strategies. Higher education institutions strive to make educational resources accessible to diverse audiences while minimising environmental impact, making the findings of the current study pertinent to HEIs' broader goals. Understanding emerging research themes and trends can also guide the development of curricula and research agendas related

to SDT strategies. Sustainable digital transformation's role in education allows stakeholders to make informed decisions that foster both innovation and resilience. In integrating diverse methodologies and perspectives, future studies can uncover the complexities of DT in education, paving the way for more effective strategies that address both opportunities and challenges. This holistic perspective will not only enhance the academic discourse but also provide practical insights for educators and policymakers aiming to navigate the evolving landscape of digital education effectively. Additionally, HEIs should adopt a culture of continuous improvement, regularly seeking feedback from students and faculty to refine digital tools and teaching methods. This iterative process can lead to more effective educational practices and better student outcomes.

Ultimately, embracing this multifaceted approach can lead to the development of targeted interventions that support students and educators alike, maximising the benefits of digitalisation while mitigating its potential drawbacks. Such interventions may include personalised learning experiences, enhanced teacher training programs, and the incorporation of emerging technologies that facilitate collaboration and engagement in virtual environments. Furthermore, the integration of these technologies will enable people worldwide to access education, regardless of their location. Additionally, in the knowledge economy era, embracing DT in the education sector can ensure open knowledge and innovation by making information widely accessible.

In the following chapter, Chapter Three, the South African higher education landscape is explored to examine the policies and institutional landscape within the South African TVET sector.

Chapter Three: Landscape of the South African TVET sector and Related Works

The preceding chapter reviewed literature on Sustainable Digital Transformation strategies, highlighting trends and critical topics including information technologies, DT, innovation, and sustainability. This chapter Three reviews related works and subsequently provides a comprehensive understanding of the SDT strategies and the institutional digital landscape within the South African Technical and Vocational Education and Training sector. The chapter outlines the long-term implications of DT in TVET, influencing not only educational practices but also broader socioeconomic outcomes. It highlights the intersection of education, technology, and industry needs within the era of the Fourth Industrial Revolution. The chapter explores best practices for implementing sustainable development strategies and frameworks for DT in higher education.

The chapter is structured as follows: Section 3.1 introduces the chapter, and Section 3.2 discusses the need for science education in South Africa. Section 3.3 addresses the challenges in South Africa's higher education, while Section 3.4 explores best practices for implementing SDT strategies. Section 3.5 concludes the chapter.

3.1 Introduction

Research on digital delivery systems for TVET programs in South Africa is limited, with room for deeper exploration into integrating digital technologies into practical pedagogical approaches and industry needs (Denhere and Moloi, 2021a; Dlamini, Ramatsetse, Zenda, Gorimbo and Mpungose, 2024). Moreover, a challenge is that a clear and comprehensive digital strategy plan should drive the implementation of digital resources to meet the needs of South African higher education institutions.

To enable institutions to transition to digital platforms successfully, they must allocate sufficient resources towards technology, training, and support services (Tewe, Ismaila, Beneke and Siewe, 2023). Sustainable digital transformation strategies in education encompass a continuous process that fosters innovative pedagogical approaches while ensuring equitable access to quality education. This includes integrating digital technologies that not only promote sustainability but also enhance learning outcomes and equip students with the skills necessary to thrive in the modern workforce.

The concept of the sustainability framework is fundamentally rooted in the TBL paradigm, which emphasises the importance of environmental, social, and economic sustainability. In adopting SDT strategies, educational institutions can create learning environments that are not only technologically

advanced but also socially responsible and economically viable. This holistic approach is essential for preparing students to meet the challenges of an increasingly complex and interconnected world. In support of the above, Ndaba and Naidoo (2024) identify DT as one of the predominant megatrends shaping 21st-century higher education institutions. This is evident in the widespread adoption of 4IR technologies, including Artificial Intelligence (AI), Blockchain, Cloud Computing (CC), Augmented Reality (AR), and Internet of Things (IoT), to enhance student learning and employee workflows. Rather than replacing employees with 4IR technologies, the DT of HEIs should focus on advancing and augmenting student capabilities.

Qolamani and Mohammed (2023) argue that a top manager may incorrectly implement an SDT strategy from their own perspective, without considering the perspectives of all parties involved. As a result, there is a need for HEIs to address issues related to establishing a digital mindset among stakeholders at all levels (Ajani and Dlomo, 2024; Westergren et al., 2024). Such an approach may ensure that all parties involved can voice their concerns about the strategies being implemented.

3.2 Importance of South African TVET colleges

The government established Technical and Vocational Education and Training colleges to improve post-school education and training in labour market skills for the South African majority, who had previously been denied access to technical and vocational education during apartheid (Sebola, 2022). In response to the goals established within the rapidly evolving technological landscape, educators and administrators in TVET institutions are shifting from manual processes to digital systems (Reddy, Chaudhary and Hussein, 2023). The progression from manual to digital processes is evident in the introduction of Learning Management Systems (LMS), such as Moodle or Sakai, in teaching and learning (Holler et al., 2023; Dlamini, Ramatsetse, Zenda, Gorimbo and Mpungose, 2024).

Moosa et al. (2023) point out that the necessity for ICT in education is emphasised in the South African government's White Paper on e-learning. According to Moosa et al. (2023) as noted in the White Paper on e-learning, successful ICT integration can enhance higher-order thinking skills, such as critical thinking, problem-solving, and creative thinking, thereby improving employability. In an emerging economy such as South Africa, there is a significant need to leverage technology within the realm of science, technology, engineering, and mathematics (STEM) education to advance knowledge acquisition. A study by Dlamini et al. (2024) argues that a significant skills mismatch in South Africa exists, where the demand for a highly skilled workforce in HEIs varies, with poor student performance in critical subjects like Mathematics. Moreso, there remains a contrast which contributes to ongoing economic inequalities and hinders poverty eradication efforts.

For many years, TVET colleges in South Africa have played a central role in meeting the industry's needs and qualification requirements for apprenticeship programs. As digital technologies advance, workplaces transform significantly, with workplace technology evolving to include mobile, CC, and IoT solutions (Westergren et al., 2024). The pace of technological innovation, especially in AI, machine learning (ML), and digital platforms, has accelerated dramatically over the past decade (Zhou, Wang, Ma and Xu, 2024). Recently, Kumar, Dhingra and Falwadiya (2023) forecasts that from 2022 to 2030, the number of IoT devices is expected to grow from 15.1 billion to 29.4 billion by 2030. Westergren et al. (2024) caution that further research is urgently needed to explore the institutional and cultural implications of IoT adoption. The increasing integration of IoT technologies in educational environments reflects a growing recognition of their transformative potential, while also highlighting the challenges that must be navigated within specific cultural and institutional contexts. As academic institutions strive to enhance learning experiences and operational efficiencies, IoT offers innovative solutions that can reshape pedagogical practices and administrative processes.

Automation and digitalisation transform people's tasks, increasing productivity and a skills gap. Workers need to reskill to become proficient in using the new digital technology. As mentioned above, the primary question is whether TVET colleges possess the specific digital technologies necessary to address market changes and needs.

As the world rapidly shifts toward digital spaces, TVET colleges feel the impact of delivering educational content through digital technologies like mobile devices and online learning platforms (Denhere and Moloi, 2021b). This transition is not merely a trend but a critical response to the demands of various industry organisations seeking to reskill their workforces with minimal disruption to production processes. This rapid change requires TVET colleges to urgently reevaluate if the institutions are well-equipped and ready for change. The urgency arises from industries actively reskilling their workforce and the growing expectation from educational institutions to produce digitally skilled graduates. The revaluation involves examining whether these institutions have the necessary infrastructure, resources, and pedagogical strategies to implement digital learning effectively.

South African TVET colleges must proactively address these challenges and ensure that their students possess the skills and knowledge necessary to thrive in the modern workforce. In incorporating technologies such as mobile devices and online learning platforms, TVET institutions can provide flexible learning opportunities that cater to diverse student needs. The process of DT should be viewed as an ongoing journey rather than a one-time initiative. Institutions must regularly assess their

digital strategies, gather feedback from stakeholders, and adapt their approaches in response to emerging trends and challenges in the educational landscape.

Denhere and Moloi (2021a) reviews the use of digital technologies in South African TVET colleges, revealing significant gaps in technology adoption. Specifically, Denhere and Moloi (2021a) posit that only 19% of TVET colleges use smart or interactive boards, while 50% employ some form of learning management system for teaching and learning. Additionally, 27% of these institutions use Microsoft Teams, and merely 12% use Zoom for online classes. The study also showed that only 54% of academic staff are competent in using these technologies. This data underscores the challenges that TVET colleges face in integrating modern educational technologies, highlighting the need for strategic investments and training to enhance digital capabilities within these institutions. Furthermore, Allais and Wedekind (2020) add that more research is needed to understand the effectiveness of online and blended learning in TVET colleges, identify student and instructor challenges, and develop strategies for improved engagement and results. As industry demands evolve, it is fundamental for TVET colleges to adapt their teaching methodologies and embrace digital solutions to remain relevant and effective in preparing students for the workforce.

Makgato (2019) posits that addressing the issue of TVET colleges may welcome the integration of digital tools and platforms, which have considerably improved the delivery of vocational education by allowing for more participatory and adaptable learning environments. On the other side, Holler (2023) adds that these strategies include the implementation of Moodle as an LMS and other digital tools that allow for both synchronous and asynchronous learning. This transformation addresses technical improvements and aligns TVET colleges with the 4IR expectations, ensuring graduates are better prepared for the changing employment market (Makgato, 2019; Khoza, 2024). The need for a highly skilled workforce in the 4IR era requires educational institutions to teach and equip their students with knowledge and skills related to 4IR advancements (Kana and Letaba, 2024; Moosa et al., 2023). Research indicates that some TVET colleges have begun integrating robotics into their curricula to meet 4IR requirements, thereby enhancing the skill sets of both educators and students in DT (Kana and Letaba, 2024). Furthermore, for students to fully engage in learning activities, mastering various technologies and digital competencies is essential (Holler et al., 2023).

3.3 Challenges

Much of the current literature (Hamadi and El-Den, 2024; Kana and Letaba, 2024; Khoza, 2024) on SDT strategies explores challenges experienced by HEIs undertaking DT. HEIs encounter numerous challenges, including resistance to change, limited resources for sustainable initiatives, increased workload, and insufficient staff capacity to support new teaching and learning methods (Hamadi and

El-Den, 2024; Mabidi, 2024). For instance, educators who have transitioned from traditional teaching methods often prefer familiar tools like WhatsApp over more formal platforms such as Zoom or Google Classroom (Mabidi, 2024).

These challenges represent significant barriers to implementing SDT strategic objectives and are discussed in detail in subsequent sections of the literature. Exploring these issues is essential for understanding how HEIs can navigate the complexities of DT while striving to achieve sustainability in their educational practices.

3.3.1 Digital gap

One of the biggest impediments is the sizeable digital gap, defined by unequal access to technical resources across students and institutions (Khoza, 2024). In support of the above, Chomunorwa, Mashonganyika and Marevesa (2023) posit that the discussion of primary limitations, such as the digital divide, should take place and address the issue of unequal access to technology and the Internet among students. Moosa et al. (2023) claim that research on ICT integration in STEM subjects is limited at the school and university levels. In South Africa, this divide is particularly pronounced, with students from underprivileged backgrounds often lacking access to essential digital tools necessary for engaging with STEM subjects (Khoza, 2024).

The digital divide exacerbates educational inequalities, creating significant challenges for the effective implementation of digital technology tools across diverse student populations (Ajani and Dlomo, 2024). In South Africa, language barriers are a significant issue, as English dominates the digital space. This dominance limits engagement for both students and educators who are not native speakers, thereby hindering their ability to fully participate in digital learning environments (Chomunorwa et al., 2023).

However, in other developing countries such as Kenya, the landscape is somewhat different. While English is also a dominant language in Kenya's educational system, there is a growing emphasis on incorporating local languages into digital content (Orwenjo, 2021). This approach not only fosters inclusivity but also enhances comprehension and engagement among students who may struggle with the English language. In recognising and valuing linguistic diversity, Kenyan educational initiatives aim to bridge the gap between technology and local contexts, thereby empowering students from various backgrounds (Orwenjo, 2021).

An alternative perspective is that English should continue to dominate in the digital space. This view posits that a common language can facilitate broader communication and collaboration in an increasingly interconnected world. Proponents of this argument suggest that prioritising English can

enhance access to global resources and opportunities for students, ultimately preparing the students for a competitive job market (Kurilovas and Kubilinskiene, 2020; Khohliso et al., 2024).

Despite these differing views, it is fundamental to acknowledge that relying solely on English may inadvertently marginalise non-native speakers and exacerbate existing inequalities. Therefore, a balanced approach that incorporates both English and local languages could be more effective in addressing the digital divide. In fostering an inclusive digital environment that values linguistic diversity while maintaining a common language for broader communication, educational institutions can better support all students in navigating the complexities of digital education.

There exists a further risk of overreliance on digital tools, which can inadvertently exclude students who lack access to these resources. Thus, it creates disparities in learning opportunities and hinders the development of critical thinking and problem-solving skills that are essential for sustainability education. In South Africa, TVET colleges focus on vocational and artisanal education, playing a foundational role in combating unemployment and poverty in Africa. Kana and Letaba (2024) argue that South Africa's unemployment rate is at a high of 34.9%. In a comment on the 2019 iteration of the Trends in International Mathematics and Science Study (TIMSS), Moosa et al. (2023) note that South Africa continues to rank at the lower end among participating countries. The performance of South African school learners in international benchmark tests, such as TIMSS, raises significant concerns. In response, the South African government is working to enhance education through technology, aiming to address historical inequalities.

Chomunorwa et al. (2023) posit that the COVID-19 pandemic sparked a surge in DT in the South African education system despite implementing policies to improve teaching and learning through digitalisation. Holler (2023) highlights infrastructure disparities, particularly in rural areas, limiting digital learning and exacerbating socioeconomic inequalities. The widening educational gap represents a significant barrier and challenge for SDT strategies in TVET colleges. A study conducted by Nosratabadi, Atobishi and Hegedűs (2023) posits that to ensure that digitalisation benefits all European citizens, it is important to address the social sustainability of digital transformation (SOSDIT) in Europe. The researchers explore the societal impact of technology and highlight the critical role of social sustainability in DT. Furthermore, social inclusion is defined as the active participation of all individuals, regardless of their background, identity, or circumstances, in societal processes. This includes ensuring equal access to resources, services, and opportunities while fostering diversity and combating discrimination and prejudice. In the digital era, technology and Internet access have the potential to significantly enhance social inclusion by connecting individuals and providing access to previously inaccessible information and resources. The study findings

indicate that digital inclusion and digital skills are pivotal factors in shaping SOSDIT and significantly impact a nation's capacity to attain the SDGs.

A study conducted by Chomunorwa et al. (2023) suggests several strategies to address the challenges of DT in South Africa, such as implementing recommendations from various commissions aimed at improving digital technology integration in education. While South Africa has the potential to transform its education system through digital means, significant efforts are required to overcome existing challenges and ensure equitable access to educational resources for all citizens, such as encouraging the use of free educational apps and resources.

3.3.2 The digital literacy skills of staff and students

Digital literacy encompasses individuals' skills and competencies in accessing, navigating, and using various technological tools (Eden et al, 2024). All educators need digital literacy skills regardless of their expertise level, significantly impacting students' learning processes and digital development (Razak, Rasli, Subhan, Ahmad and Malik, 2023). Given the growing reliance on online platforms for information, students need to acquire the digital skills to navigate these platforms safely, including online privacy and cybersecurity (Eden et al., 2024; Gombár et al., 2024). Educator willingness is foundational for effective ICT integration in lessons, as Technophobic educators are less likely to use ICT despite access and training (Moosa et al., 2023). To deter educators from reverting to traditional methods when facing issues, professional development opportunities are necessary for building educator confidence.

Similar to basic education, TVET institutions face challenges in effectively integrating ICT into their curricula. As indicated by Moosa et al. (2023), there is limited progress in ICT integration in STEM subjects, which is also applicable to TVET institutions, where practical skills and technology use are essential. The study highlights the need for professional development activities to enhance teachers' ICT integration skills. This is particularly relevant for TVET educators who must stay updated with technological advancements and pedagogical strategies.

3.3.2.1 Strategies for enhancing digital literacy in HEIs

Vujovic, Jonathan, and Hacks (2024) suggest that people with limited technological skills may need help accessing vital digital resources for various job functions due to inadequate training. Correspondingly, Chomunorwa et al. (2023) further reveal that researchers must explore how to equip TVET educators with the necessary knowledge and skills for 21st-century classrooms and workforces, highlighting the need to investigate effective professional development strategies. Educators must receive training and development to equip themselves with digital competencies and skills (Moosa et al., 2023; Dlamini et al., 2024).

A 2020 study found that a public institution implementing DT should ensure educators are competent to deliver content on digital platforms (Yureva, Burganova, Kukushkina, Myagkov and Syradoev, 2020). To ensure the effective integration of technological platforms into teaching and learning, a staggered approach to practical training is essential. Developing clear training plans is fundamental for this process, as they provide structured guidance for educators and support staff in adapting to new technologies (Mabidi, 2024). In promoting an environment where educators are equipped with the necessary skills and knowledge, institutions can enhance the overall educational experience.

According to Canal, Obesso, and Rivera (2024), a gap exists in the literature, which primarily focuses on students' digital skills rather than those of educators. Using the Digital Teaching Competence Questionnaire (DigCompEdu) to investigate the relationship between digital competence and learning outcomes, paving the way for future studies in this critical area of education. They report that while educators' digital skills may enhance students' learning perceptions, they do not necessarily translate into improved academic performance. Surprisingly, students rated their educators' digital skills as medium to high, which was unexpected, given that Canal et al. (2024) had anticipated lower ratings. However, there is a relationship between educators' professional commitment and their digital teaching skills, which positively influences students' perception of learning.

Implementing SDT strategies in higher education also requires educators to be prepared to work under new conditions facilitated by DT (Akhmetshin, Barmuta, Vasilev, Okagbue and Ijezie, 2020). On the other hand, when educators possess strong digital skills, they can create more engaging and effective learning environments, which is vital for the success of DT initiatives. The transition to a digitalised education system presents challenges for educators, who may be accustomed to traditional teaching methods (Canal et al., 2024; Hamadi and El-Den, 2024). One of the key challenges identified in the literature is that many academics have historically focused on their specific fields of knowledge rather than on integrating technology into their educational practices. It is more important to impart the subject material than fiddle around with gadgets. This shift requires a change in mindset and skill development to meet the demands of a digitalised educational framework. Professional development programs should emphasise the importance of integrating technology in a way that complements and enriches the educational experience, thereby encouraging academics to embrace digital tools as essential components of their teaching practices.

Obesso et al. (2023) suggest that digital literacy in higher education should be part of the institution's strategic management and development plan. Furthermore, it is imperative that various institutions, such as TVET colleges, address the training and development needs of multiple stakeholders, including staff, educators, and students. An investment in DT by various policymakers that addresses

issues related to digital inclusion and digital literacy can positively impact TVET colleges (Jekabsone and Gudele, 2023; Nosratabadi et al., 2023; Ajani and Dlomo, 2024; Dlamini et al., 2024). The adoption of e-learning methods, such as blended learning, has begun to replace traditional face-to-face classes (Hamadi and El-Den, 2024). This shift is supported by Web-based training that allows students to access materials at their convenience and at their own pace.

The use of online learning management systems has raised concerns about the readiness of TVET colleges for the 4IR (Allais and Wedekind, 2020). According to Eden et al. (2024), educators consider the use of ICT essential and acknowledge the necessity of enhancing their digital skills to effectively support students in comprehending diverse subjects. A study conducted by Selwyn (2021) advocates for a sustainable approach to educational technology, involving co-evolving and co-creating solutions that benefit both humanity and the environment. Villarroel Henríquez and Stuardo Troncoso (2022) directly address the need for HEIs to develop digital skills for sustainable educational technology (EdTech) solutions. The study focuses on teacher training, which contributes to an HEI's overall DT strategy. Developing digital skills for educators and students is a fundamental aspect of DT in HEI (Selwyn, 2021; Obesso et al., 2023).

As indicated by Reddy et al. (2023), highlighting the importance of creating systematic digital literacy and instruction design courses. Creating systematic digital literacy and instruction design courses enables educators to enhance unique educational approaches and nurture a mindset of digital competence. Additionally, equal learning approaches, such as blended learning, advance the sustainability of digital learning (Kana and Letaba, 2024; Mbatha, Buthelezi and Ajani, 2024). These models are tailored to meet the diverse learning needs of students, accommodating all students (Mbatha et al., 2024). Thus, approaches such as disability support are examples of strategies that would bring about sustainable digitalisation in TVET colleges.

An example of a highly relevant study on the SDT strategies being implemented in HEIs worldwide is Kennedy and Laurillard (2019), addressing the use of digital technology, specifically MOOCs, for teacher professional development (TPD) in the context of mass displacement. Kennedy and Laurillard (2019) investigated the viability of scaling up TPD through co-designed MOOCs and emphasised the importance of having a sustainability plan in place from the outset. The study includes a case study from Lebanon, which has the highest proportion of refugees in host communities worldwide. The study provides valuable insight into the challenges and opportunities of implementing digital TPD in the context of mass displacement and limited digital infrastructure. The study employs a co-design methodology to develop a self-sustaining digital TPD that could serve as a model for other contexts facing similar challenges. The innovative approach adds to understanding effective DT strategies in

higher education. Kennedy and Laurillard (2019) focus on teacher professional development in the context of refugee education, which diverges from the broader academic and research objectives typically associated with most higher education institutions. While MOOCs can be valuable tools for SDT strategies, their application in refugee education may need to be adapted for implementation within the established frameworks of higher education institutions.

These MOOCs are increasingly relevant in higher education, mainly when providing opportunities for distance education, which has become more critical in the context of the COVID-19 pandemic (Martínez-Pérez, Cabero-Almenara, Barroso-Osuna and Palacios-Rodríguez, 2022). According to Martínez-Pérez et al. (2022), who focus on using MOOCs for educator development and student learning in HEIs, examining the development of digital competencies in educators and students is a critical aspect of SDT in higher education. Understanding how MOOCs can contribute to enhancing digital competencies aligns with the goals of SDT strategies in educational institutions.

Martínez-Pérez et al. (2022) explore how MOOCs can foster autonomous and collaborative learning in innovative scenarios, aligning with SD objectives and exploring Learning Technologies, specifically, MOOCs as a tool for developing teacher competencies applicable in HEIs. The study connects T-MOOCs with the SDGs and open education. T-MOOC for Initial Teacher Training in Digital Competencies: Technology and Educational Innovation (Martínez-Pérez et al., 2022). The study demonstrates a commitment to promoting sustainability through educational initiatives by incorporating the United Nations SDG guidelines. To add credibility to the findings and contribute valuable insights into the effectiveness of MOOCs in developing digital competencies and supporting sustainable learning practices. The study by Martínez-Pérez et al. (2022) provides empirical evidence based on data from 313 students with a Primary Education Degree from the University of Seville, Spain. They used two online questionnaires: the Digital Teaching Competence Questionnaire (DigCompEdu) and the Content Questionnaire. The study offers practical implications for HEIs seeking to integrate SDT strategies into their curriculum. The actions proposed as a result of the study include consolidating the course content, creating a training and innovative environment, and evaluating MOOCs as resources for autonomous and collaborative learning. Educator training is valuable because faculty development is essential for successful DT in HEIs, but may not be an overall HEI strategy. With links to the UN Sustainable Development Goals and open education, the exploration of T-MOOCs is a potential tool for developing digital competencies in faculty.

Given that educator training is a fundamental aspect of higher education institutions' educational programs, it is pertinent to examine how prospective educators view digital teaching competence and its connection to sustainability objectives concerning HEIs' DT strategies. (Ortega-Sánchez and

Gómez-Trigueros, 2019) examine the perception of future educators about digital teaching competence and the potential contribution of educational technologies to achieving the SDGs. The researchers specifically address the possible contribution of educational technologies, such as MOOCs, to fulfilling the SDGs. The potential contribution of educational technologies aligns well with the more prominent theme of sustainability in HEIs and provides insight into how DT strategies support sustainability initiatives within academic contexts. Ortega-Sánchez and Gómez-Trigueros (2019) used a quantitative analysis of data collected through a validated questionnaire, indicating a methodologically sound approach to investigating future educators' perceptions. The methodological rigour adds credibility to the findings and enhances their applicability to discussions around SDT strategies in HEIs. Despite positive student feedback regarding the suitability of MOOCs for their training. They conclude that significant challenges remain in optimising professional development programs for HEI educators to fully meet the evolving needs of contemporary society.

To successfully integrate digital technologies into higher education, educators need robust EdTech skills to transform teaching and learning. The need for educators to be equipped with EdTech skills to transform teaching and learning practices in HEI is highly relevant to the topic of DT in higher education. Faculty development initiatives must equip educators with the competencies for sustainable EdTech practices. Research, such as that by Villarroel Henríquez and Stuardo Troncoso (2022), underscores the critical importance of addressing the digital divide between educators and students, a challenge exacerbated by the COVID-19 pandemic. They focus on the need for educator training in digital skills, a fundamental aspect of DT in HEIs, and the importance of moving beyond technical skills towards integrating digital technology into pedagogical practices effectively (Allais and Wedekind, 2020; Sebola, 2022). Villarroel Henríquez and Stuardo Troncoso (2022) discuss the significance of sustainable EdTech, aligning with the broader goal of sustainability in DT strategies. The ethical, responsible, and cooperative use of technologies is an essential consideration for HEIs. Consequently, Villarroel Henríquez and Stuardo Troncoso (2022) propose a training program in EdTeach that integrates digital technology into educational tasks, addressing the complexity of student learning needs. The need for educators to be equipped with digital skills to implement sustainable EdTech practices effectively is a foundational aspect of designing effective DT strategies in higher education.

3.3.2.2 Need for continuous professional development

Hamadi and El-Den (2024) claim that there is insufficient digital literacy among students and educators, which obstructs the effective and efficient utilisation of digital tools in teaching and learning. To effectively integrate digital tools such as AI, continuous professional development (CPD) for educators is essential. Educators must be equipped with the necessary skills and knowledge

to use digital tools responsibly and effectively in their teaching practices. Even when TVET colleges plan to train educators, financial constraints and lack of support often hinder the implementation of comprehensive training and CPD programs, resulting in inconsistent training outcomes (Kana and Letaba, 2024; Mesuwini and Mokoena, 2024). A further hindrance is policy uncertainty, as clarity in policy implementation is often lacking, hindering ICT integration (Moosa et al., 2023; Dlamini et al., 2024). Ongoing training initiatives are necessary to empower educators in the evolving educational landscape. The training initiatives must be comprehensive training programs for educators to integrate digital technologies, such as AI, effectively (Abulibdeh et al., 2024).

Educational institutions often face resistance to change from educators and administrators (Timbula and Marvadi, 2023; Abulibdeh et al., 2024). Implementing digital technology-driven education requires significant shifts in curriculum design and teaching methods, which can be met with reluctance from stakeholders. The resistance can impede the adoption of innovative approaches necessary for effective education. The fast pace of technological advancements in Industry 4.0 makes it difficult for educational institutions to keep their curricula and digital technology tools up to date. The challenge is particularly relevant for SDT strategies, which require a holistic and integrated approach to education (Abulibdeh et al., 2024; Ajani and Dlomo, 2024). Moreover, Kana and Letaba (2024) offered an unwarranted characterisation that academics are considered novices who learn from what the DHET and its partners dictate. This leads to the exclusion of TVET staff from the curriculum development process, including the DT journey. The exclusion renders the adoption of digital technology by TVET college educators unfeasible (Mbatha et al., 2024).

An assertion by Allais and Wedekind (2020) is that TVET colleges frequently use restrictive pedagogical models that emphasise formal knowledge at the expense of practical application, potentially hindering the integration of technology into the curriculum. There is a need to equip students with practical skills that can lead to entrepreneurship and employment opportunities (Dlamini et al., 2024). Stressing that without a focus on practical skills, the potential for economic development is compromised. Furthermore, the researchers dispute the notion that an increase in student enrolment or the establishment of more TVET colleges will result in better employment outcomes. As the manufacturing industry in South Africa is underdeveloped, this limits job opportunities for graduates.

A study by Miglionico (2022) investigates the use of digital technologies for climate risk management and sustainability reporting in financial institutions. Although it focuses on a different sector, it underscores the importance of data standardisation and transparency in sustainability initiatives. Higher education institutions can adopt similar data management approaches when implementing

SDT strategies. The study's focus on leveraging technology to align corporate disclosure with climate change policy objectives is pertinent to the broader sustainability agenda, including the United Nations' SDGs. The study is relevant to HEIs' sustainability efforts, as they often align their initiatives with the SDGs. Despite its primary focus on financial institutions, the insights and methodologies presented could apply to HEIs. Understanding how digital technologies can address sustainability challenges and improve decision-making processes may aid in strategic planning within HEIs (Ajani and Dlomo, 2024; Chen et al., 2023).

The increasing integration of digital technologies in higher education necessitates a critical examination of how professionals adjust to this evolving landscape. The evolution has given rise to concepts such as 'digital professionalism,' which emphasises the importance of individuals possessing a diverse range of skills and competencies to navigate and succeed effectively in a digitally driven environment. Findings from related studies apply to HEIs, enabling them to leverage technology for enhancing operational efficiency, improving student services, and expanding outreach (Chomunorwa et al., 2023; Timbula and Marvadi, 2023; Canal et al., 2024). While focusing on DT in microfinance institutions (MFIs), Timbula and Marvadi (2023) highlight the broader importance of understanding employees' technology adoption during DT. However, the microfinance context differs significantly from that of HEIs. The primary focus of the study is on MFIs in Ethiopia, the broader theme of DT through the acceptance and use of technology is highly relevant to HEIs. Like financial institutions, universities and colleges increasingly leverage technology to improve operational efficiency, improve student services, and expand outreach.

Timbula and Marvadi (2023) examine the factors that influence employees' intention to accept and use technology, including expectations of performance and effort, social influence, and facilitative conditions. Understanding these factors is fundamental for HEIs seeking to implement SDT strategies, considering the attitudes and behaviours of faculty and staff toward technology adoption (Mabidi, 2024; Ndaba and Naidoo, 2024). The researchers Timbula and Marvadi (2023) use structural equation modelling (SEM) to analyse survey data from 12 self-administered questionnaires, adding robustness to the study findings. Structural equation modelling allows the examination of complex relationships among multiple variables, providing valuable insights into the dynamics of technology acceptance among employees. The findings on employee behaviour in financial institutions may not directly apply to faculty and staff in HEIs.

The study by Timbula and Marvadi (2023) indicates that performance expectancy, effort expectancy, and social influence positively affect technology acceptance. Behavioural intention mediates the relationship between these factors and user behaviour. The Ethiopian study indicates that employees

generally accept new technology, aiding operational efficiency. At TVET colleges, understanding the motivations and intentions of both staff and students towards using digital tools can help in designing interventions that promote positive attitudes towards technology adoption (Mabidi, 2024). Management should recognise the potential benefits of adopting new technologies and establish strategic plans to maximise these advantages. Similarly, South African TVET colleges can benefit from strategic planning that aligns DT initiatives with their educational goals and students' needs.

Rollnik-Sadowska (2024) studied the labour market in the context of sustainability transitions. Identifying emerging research directions and methods, including analysing topics such as DT, is highly relevant to the broader DT context across sectors, including higher education. Rollnik-Sadowska (2024) employed a bibliometric analysis method to review the literature from the SCOPUS database. The bibliometric analysis provided a systematic and comprehensive overview of the literature on labour markets in sustainability transitions, including insights into trends, thematic clusters, and research methods. Rollnik-Sadowska (2024) identified four thematic clusters: green growth, twin transition, green employment, and sustainable European labour-market policy. While these clusters may not directly focus on DT, they provide valuable context and information on broader sustainability initiatives, forming DT strategies in higher education. Furthermore, Rollnik-Sadowska (2024) highlights several topics that researchers need to sufficiently explore, including DT, AI, and the future of work. These research gaps underscore the importance of further investigating the intersection of DT and sustainability transitions, particularly for HEIs undertaking DT efforts.

Rollnik-Sadowska (2024) explores the relationship between the labour market and sustainability transitions, a broader topic compared to the specific context of HEIs. Consequently, Rollnik-Sadowska (2024) emphasises the growing need for education and training programs that equip individuals with the skills necessary for sustainability-related careers. This is particularly relevant for TVET colleges, which play a foundational role in providing vocational training aligned with sustainable practices. The findings indicate that labour-market sustainability transitions vary markedly across regions. This suggests that South African TVET colleges may need to tailor their approaches to local contexts and industry needs, ensuring that their training programs are relevant to the specific sustainability challenges faced in South Africa. Researchers identify DT as an under-researched topic that impacts the workforce across various sectors, including higher education (Chomunorwa et al., 2023; Westergren et al., 2024).

3.3.2.3 Digital privacy and cybersecurity

Digital privacy and cybersecurity are critical components of DT in higher education. Institutions must invest in robust cybersecurity measures, foster a culture of awareness, and ensure compliance with

regulations to protect sensitive data and maintain trust within the academic community. In agreement with Ajani and Dlomo (2024) that the increased reliance on digital solutions in higher education has indeed expanded the potential for cyber threats, necessitating robust cybersecurity measures. The current study notes that data breaches have become a primary risk, with colleges and universities ranking third in such incidents, as reported in recent studies (Van Staden and Naidoo, 2022; Khoza, 2024). This allows cybercriminals to exploit various vulnerabilities, including weak networks and systems, particularly as faculty and students increasingly engage with cloud-based platforms that handle sensitive information. Therefore, higher education institutions must implement comprehensive cybersecurity measures, including adopting a Zero Trust framework, minimising the attack surface and enhancing cybersecurity posture by preventing lateral movement within networks (Mkhulisi, 2025; Regula, 2025). Furthermore, as ransomware attacks surge, securing cyber insurance has become increasingly difficult for HEIs due to the high frequency and severity of claims. Institutions must demonstrate effective cybersecurity practices to improve their insurability (Mkhulisi, 2025; Regula, 2025). Consequently, South African HEIs are encouraged to invest in advanced cybersecurity measures and strategies to protect their data, reputation, and financial health in an increasingly digital environment. The integration of digital technology in education raises concerns about data privacy and cybersecurity. Nosratabadi et al. (2023) examined the relationship between human rights protection, digital privacy, cybersecurity, and SOSDIT across 27 European countries. Hypothesised that Digital Privacy and Cybersecurity: The level of protection for individuals' data and online privacy, was a factor influencing the overall SOSDIT of a country. The findings of Nosratabadi et al. (2023) reveal strong evidence for the impact of digital inclusion and digital skills. However, due to data quality issues, the researchers had to exclude digital privacy and cybersecurity from their analysis. Ensuring that student data is protected while utilising digital technology tools is a critical challenge that institutions must navigate to maintain trust and compliance with regulations (Abulibdeh et al., 2024).

Educators are essential in teaching students safe online practices and informed decision-making. Digital literacy is critical in preparing graduates for the competitive job market (Khan, Sarwar, Chen and Khan, 2022). Public institutions must strategically equip students and educators with the digital skills necessary to harness the benefits of DT. From basic skills in using digital devices and applications, navigating online platforms and managing digital tools effectively. To apply digital tools to analyse problems and generate solutions, including effective communication in a virtual environment.

In Gombár et al. (2024), the study analysed students' opinions on cybersecurity risks in Slovakia and the Czech Republic. The sample included 964 respondents, with age distribution analysed as an

ordinal variable. The majority of respondents (69.4%) were under 25 years old; a few were over 55. The research instrument's reliability was high, with Cronbach's alpha at 0.95047. The findings highlight significant differences in risk perception between the two groups. The findings indicate that insufficient resources and outdated infrastructure pose substantial risks.

In the context of South African TVET institutions, investing in modern IT infrastructure and cybersecurity training is fundamental to ensure they can effectively respond to cyber threats and maintain operational continuity. The researchers Gombár et al. (2024) emphasise that cybersecurity is a critical pillar within the framework of Industry 4.0 DT. The increasing reliance on digital solutions in higher education has markedly expanded the attack surface for potential cyber threats. As a result, robust cybersecurity measures are paramount for protecting sensitive data and maintaining the operational integrity of South African TVET colleges. Gombár et al. (2024) further highlight the increasing vulnerability of institutions to hybrid threats, which can disrupt operations and compromise data security. Technical and Vocational Education and Training institutions in South Africa must be aware of these threats and develop strategies to mitigate risks, ensuring a sustainable digital environment. Additionally, Gombár et al. (2024) discuss the significance of understanding risk perception among individuals, which is fundamental for decision-makers in educational institutions. In nurturing a culture of cybersecurity awareness and training, TVET institutions can enhance their resilience against cyber threats, ultimately supporting sustainable digital strategies (Van Staden and Naidoo, 2022; Khoza, 2024).

Consequently, Gombár et al. (2024) advocate for collaboration between government, private sectors, and academia to address evolving cybersecurity challenges. South African TVET institutions can benefit from partnerships that enhance their cybersecurity frameworks and promote knowledge sharing, which is vital for sustainable transformation in the digital landscape. Given the imperative for adaptability and proactive strategies, TVET institutions in South Africa must prioritise agility in their approach to DT, ensuring that the strategies are both sustainable and resilient in the face of future challenges.

3.3.3 Resources and infrastructure

According to the resource allocation theory, institutions often prioritise resources for production activities that yield immediate economic benefits (Sun et al., 2023). This tendency can lead to underinvestment in corporate social responsibility (CSR) practices, as CSR initiatives may not provide direct financial returns. Digital transformation plays a critical role in addressing inefficiencies in resource allocation. In integrating various resources such as technology, information, capital, and talent, it enhances overall resource allocation efficiency within institutions. This improved efficiency

enables institutions to save resources, which can then be redirected toward fulfilling CSR obligations. Additionally, DT helps institutions integrate resources, improve allocation efficiency, and achieve highly efficient utilisation of these resources (Sun et al., 2023).

Effective learning encompasses providing students with theoretical and practical knowledge, allowing them to apply concepts and theories to develop critical and intellectual capacities (Allais and Wedekind, 2020). In establishing strong relationships with the industry through apprenticeship and artisan development programs, TVET colleges enable graduates to quickly enter the job market equipped with theoretical, practical, and workplace knowledge (Nthutang, 2022). However, the need for industry funding significantly impacts the sustainability of TVET colleges. The economic context in South Africa, characterised by high unemployment and poverty, poses significant challenges for educational institutions. Sustainable digital transformation strategies must consider these factors to ensure that digital initiatives are relevant and beneficial for students, particularly in preparing them for the job market. A study by Tewe et al. (2023) emphasises the importance of exploring alternative income streams for universities to maintain operational viability. This is equally applicable to TVET colleges, which must seek partnerships with the private sector and other funding sources to support their DT efforts. To effectively implement digital strategies and meet stakeholder needs, TVET colleges require adequate financial support. However, a noted challenge is the decrease in government funding despite increasing student enrolment, which inhibits the sector's growth (Dlamini et al., 2024).

The necessity for organisations, including TVET colleges, to invest in new technologies and upskill staff is paramount for DT. Adequate funding is essential to invest in the necessary infrastructure and staff training programs that facilitate digitalisation efforts within these institutions. However, securing sponsorship and funding for HEIs remains a significant challenge for the national government, particularly in light of South Africa's current declining economy (ETDP SETA, 2024). The financial strain often compels institutions to prioritise immediate student needs, which can detract from investments in critical resources for digital infrastructure (Mabidi, 2024).

Ndaba and Naidoo (2024) emphasise that South African HEIs should focus on investing in infrastructure that will provide long-term benefits, thereby minimising the need for frequent and costly upgrades. Ensuring that the initial investment in digital infrastructure yields sustainable returns is critical for the ongoing viability of these institutions. The challenge of securing adequate funding poses a significant barrier to the successful implementation of DT initiatives in HEIs, creating a gap between necessary change and effective transformation. The funding challenge to complete the successful implementation of DT in HEIs is a stumbling block between change and transformation.

Recent developments highlight efforts to address these funding challenges within South African TVET colleges. In 2024, the University of Johannesburg secured a substantial grant of approximately 8.1 million Rand (about $422,000) from the European Union (EU) to implement the Promotion of Technology-Enhanced Learning and Digital Education (Pro-TELDE) project. This initiative aims to drive DT in South African TVET colleges by leveraging AI to enhance educational practices and foster a culture of continuous learning and innovation (Ajani, 2024). Consequently, this initiative underscores the potential for external funding sources to support the integration of advanced technologies and enhance educational capabilities within the sector. Such collaborations could serve as a model for other institutions seeking to overcome financial constraints while advancing their DT agendas.

Researchers in South Africa have noted that public and private HEIs face unique challenges based on funding and institutional structures (Ajani and Dlomo, 2024; Ndaba and Naidoo, 2024). Public institutions may struggle with funding and bureaucratic processes, but benefit from government support. Whereas private institutions have more resources but face competition and return on investment challenges. To address these issues, it is fundamental for TVET colleges to develop strategic partnerships with both government and industry stakeholders. Such collaborations can provide additional funding and resources while fostering a shared vision for SDT. Through prioritisation of strategic alignment and enhancing financial support mechanisms, TVET colleges can better navigate the complexities of DT and ensure their long-term sustainability in an increasingly digital landscape.

According to Moosa et al. (2023), the challenge of a lack of learner access to devices and Wi-Fi issues significantly influences educators' integration of technology. The disparity in access to ICT resources between affluent and under-resourced schools is echoed in TVET institutions. Many TVET institutions struggle with inadequate infrastructure, which hampers the effective delivery of vocational training. A study by Dlamini et al. (2024) highlights the critical role of digital technology in enhancing TVET education and learning. Integrating digital tools can help address the evolving demands of the workforce, ensuring that students acquire relevant skills for the 21st century, including STEM and critical thinking skills. In a study undertaken at one of the six South African universities of Technology, Ndaba and Naidoo (2024) highlight the importance of investing in the digital competence of institutional staff. Furthermore, it is emphasised that improving the digitalisation of services is an ongoing process requiring commitment, adequate resources, and a strategic approach. However, Ndaba and Naidoo (2024) focus exclusively on support staff, omitting students and academic personnel. Consequently, the study's outcomes apply only to staff within

Universities of Technology (UoTs). They cannot be generalised to comprehensive and traditional universities, as the contexts and mandates of these institutions differ significantly.

According to Zhou et al. (2024), the emergence of advanced digital technologies, such as big data (BD), AI, and the IoT, presents a compelling opportunity for China to "leapfrog" traditional industrial development models and achieve rapid green transformation across multiple sectors. The integration of digital technologies within TVET colleges has the potential to streamline both administrative and educational processes, thereby enhancing operational efficiency and optimising resource management. Zhou et al. (2024) emphasise the importance of resource orchestration in leveraging digital resources for green innovation. Consequently, TVET colleges can apply these principles to effectively integrate digital tools and resources, enhancing their capacity to deliver sustainable education and training programs. The study by Zhou et al. (2024) highlights that while SDT can provide significant benefits, it also requires substantial investment and may lead to financial pressures that could crowd out resources for green initiatives. Given the imperative of sustainable development, TVET colleges must carefully balance their investments in DT with their commitments to sustainability. The findings suggest that managers in enterprises, including educational institutions, should focus on optimising resource allocation and leveraging both internal and external resources. Therefore, TVET colleges can use these insights to develop strategies that enhance their educational offerings while promoting sustainable practices. Furthermore, TVET colleges can play a foundational role in training students to address sustainability issues across sectors, thereby contributing to broader environmental goals in South Africa.

3.3.4 Collaboration as public-private partnerships

Dlamini et al. (2024) claim that there is a call for greater commitment from educators and administrators to adopting innovative teaching methodologies that prioritise skill development. Enhancing industrial collaboration and aligning educational practices with market needs are essential for improving the effectiveness of the TVET college sector. To achieve this, academic-industry partnerships must be prioritised to ensure education aligns with workforce demands. Through collaboration with industries, HEIs can gain insights into the current trends and demands of the job market. This collaboration allows educational institutions to tailor their curricula to include the skills and knowledge that employers are seeking, particularly in technology and entrepreneurship. This ensures that students are learning applicable skills that will enhance their employability upon graduation (Biclesanu et al., 2023; Ajani and Dlomo, 2024). Industry partners can provide valuable feedback on the effectiveness of educational programs. The intended feedback can help HEIs identify areas for improvement and innovation in teaching methods and course content, ensuring alignment with industry standards and expectations.

The present study notes that through collaboration, a good outcome may lead to the development of specialised courses or training programs that focus on emerging technologies and business practices (Gombár et al., 2024; Mesuwini and Mokoena, 2024). As a result, collaboration helps students build critical skills such as digital literacy, problem-solving, and adaptability, which are essential for success in the digital age (Chomunorwa et al., 2023). Biclesanu et al. (2023) argue that establishing strong partnerships with industry can lead to long-term collaborations that benefit both students and companies. These relationships can foster a continuous exchange of knowledge and resources, further enhancing the educational experience and ensuring that students are well-prepared for their future careers.

While there is a recognised need for strategic alignment with industry and adaptation to technological advancements, existing research indicates that weak partnerships between industry and TVET colleges significantly hamper these institutions' ability to meet industry skill needs (Denhere and Moloi, 2021b). The lack of strong industry and TVET college partnerships ultimately undermines students' ability to transition effectively into the workforce (Westergren et al., 2024). Nevertheless, ongoing collaborative initiatives between the government and the private sector aim to strengthen ICT infrastructure and provide targeted educator training, thereby addressing critical barriers and helping bridge the digital divide.

To promote SDT in South African TVET colleges, a flexible approach that considers technology and human factors is required (Kana and Letaba, 2024). Therefore, Holler (2023) noted that a viable strategy is to consider forming strong public-private partnerships to improve resource availability and infrastructure development. This collaboration between the government, the private sector, and TVET colleges is critical in providing financial, expertise, and technology resources for TVET colleges (Mesuwini and Mokoena, 2024). The success of these partnerships will help bridge the gap between modern available resources and equipment and reliable network or Internet connectivity (Kana and Letaba, 2024).

Bokolo (2022) discusses the significance of interoperability in smart city initiatives. Higher education institutions can benefit from fostering collaborations with local governments and industries to create interoperable systems that enhance data sharing and innovation, which is fundamental for SDT. Strielkowski et al. (2022), who studied SD and the DT of educational systems, conclude that collaboration between secondary schools and HEIs enhances sustainability education programs. Emphasis on self-directed learning is fundamental for effective education transformation (Strielkowski et al., 2022).

Industry partnerships can provide TVET colleges with valuable insights into industry trends and skill requirements, enabling them to develop more relevant curricula and training programs (Allais and Wedekind, 2020). The collaboration can also facilitate work-integrated learning opportunities and internships, bridging the gap between academia and industry.

3.3.5 Curriculum content

Understanding the different levels of engagement with sustainability is important for developing effective strategies (Pasi and Misuraca, 2020). Higher education institutions strive to make educational resources accessible to diverse audiences while minimising environmental impact, making this research particularly pertinent to their broader goals (Vlizos et al., 2024). Tewe et al. (2023) note the potential decline in South African educational quality due to financial constraints as a significant concern raised. At the TVET colleges, maintaining high-quality training programs is essential, especially as they transition to more digital platforms. Ensuring that students receive quality education while integrating technology is fundamental for their future employability.

Through understanding emerging research themes and trends, HEIs can guide the development of curricula and research agendas related to SDT strategies. Bloom's Taxonomy may need adaptation to incorporate AI-related skills and ethical considerations. Moreover, Moosa et al. (2023) argue that curriculum planners should replace outdated competencies with modern educational ideas. In support of the above, Abulibdeh et al. (2024) propose that a holistic curriculum is essential to equip students with the multidisciplinary skills required for Industry 4.0. To achieve this, HEIs must integrate sustainability principles into both pedagogical practices and institutional operations, ensuring meaningful societal impact. Furthermore, innovative assessment methodologies are imperative to effectively evaluate critical thinking, creativity, and other competencies central to holistic skill development. The evolution of assessment practices is therefore vital to aligning educational outcomes with the demands of a rapidly changing, technology-driven global landscape.

Emotional intelligence and adaptability are essential skills to develop alongside technical proficiency. AI integration raises concerns about student originality and the development of critical thinking. AI tools can personalise learning, but they also present challenges such as bias and privacy concerns. The ethical and legal implications of AI in education must be addressed through clear and transparent policies. The government substantially adjusted the TVET college curriculum to incorporate industry needs (Allais and Wedekind, 2020). However, TVET colleges have yet to fulfil the mandate and expectation of becoming institutions of choice and addressing skills shortages in South Africa (Nthutang, 2022). The curriculum must be adjusted to address the industry's skills, gaps, and needs (Dlamini et al., 2024). The current TVET college curriculum needs to be updated, and the

infrastructure needs to be improved to address the industry's evolving needs (Nthutang, 2022; Dlamini et al., 2024). The need to update the TVET college curriculum is evident when most TVET colleges do not offer practical education in the engineering field, instead teaching only theory, and rely on industry through apprenticeships to provide practical training to prepare students for the job market. The content of the TVET college curriculum must be kept relevant to the industry's needs through regular research reviews, industry participation, and support for curriculum development (Allais and Wedekind, 2020; Mesuwini and Mokoena, 2024).

The unequal distribution of resources markedly complicates the landscape of DT in education, as many institutions lack the necessary funding to adopt and implement digital tools effectively (Tewe et al., 2023). To address these challenges, Mabidi (2024) posits that a robust SDT strategy can provide HEIs with opportunities to enhance student enrolment through hybrid learning models. These models combine face-to-face and online education, thereby ensuring that access to quality education is not limited by socioeconomic status. The hybrid learning approach not only facilitates broader outreach but also aligns with the evolving demands of the educational sector in the context of the 4IR. Furthermore, Mabadi (2024) emphasises that the digital revolution demands a fundamental redesign of curricula to integrate digital literacy and critical thinking skills. These updates are vital for equipping students to navigate the complexities of the digital era. To achieve this, incorporating active learning strategies and student-centred teaching practices is recommended, as these approaches foster greater student engagement and improve learning outcomes (Ndaba and Naidoo, 2024).

3.3.6 Over-reliance on digital technologies

Care must be taken to avoid overreliance on digital technologies such as AI, as this can lead to significant challenges in educational settings. Research indicates that excessive dependence on AI tools may negatively impact students' critical thinking and problem-solving abilities, potentially undermining the development of essential skills necessary for their future careers (Abulibdeh et al., 2024). In addition, concerns regarding data privacy, algorithmic biases, and the transparency of AI systems further complicate the integration of these technologies in educational contexts (Gombár et al., 2024; Mkhulisi, 2025; Regula, 2025). Financial and administrative constraints pose significant challenges to the successful implementation of SDT within South African TVET colleges. As highlighted by Nthutang (2022), limited government funding, coupled with increasing student enrolment, necessitates difficult budgetary decisions. Often resulting in the prioritisation of immediate student needs over critical investments in digital infrastructure, hindering the long-term sustainability of digital initiatives (Mabidi, 2024).

The potential for bias in digital technologies, particularly in AI algorithms, poses a significant challenge. Research highlights that algorithmic bias is a critical issue in AI applications, especially in educational contexts (Abulibdeh et al., 2024). AI tools can inherit biases from the data they are trained on, leading to skewed recommendations and perpetuating existing inequalities, particularly in sustainability initiatives. Raising ethical concerns that need to be addressed to ensure fairness and inclusivity in education. The AI systems trained on biased datasets can reinforce stereotypes and disadvantage marginalised groups, thereby exacerbating existing inequalities. To mitigate these biases, it is essential to develop inclusive frameworks, diversify datasets, and promote transparency in AI processes.

In reimagining curricula for the 4IR, Sywelem (2024) proposes that AI technologies in education personalise learning experiences and support educators in administrative tasks through replicating human intelligence, thus enabling machines to perform cognitive functions. These AI systems modernise traditional frameworks, streamline decision-making processes, and enhance organisational efficiency through task automation and data analysis. Additionally, AI systems can increase student engagement through adaptive learning systems and educational games. While also configured to assist in emotional monitoring and skill recognition for tailored learning, AI systems provide personalised support, improving the learning experience and ultimately enhancing student learning outcomes (Sywelem, 2024).

Conversely, it can be argued that an overreliance on digital technologies may lead educators and students to become overly dependent on tools such as AI for decision-making and learning, potentially undermining critical thinking and problem-solving skills. This concern aligns with the broader implications of AI integration in education, where maintaining a balance between technology use and human input is essential for effective learning outcomes. In the context of South African TVET colleges, AI algorithms can inadvertently perpetuate biases present in the training data, resulting in biased assessments or recommendations that fail to accurately reflect the diverse backgrounds and capabilities of students (Abulibdeh et al., 2024). When AI systems exhibit bias, they may disadvantage certain student groups, leading to unequal learning opportunities. This issue is particularly relevant in South Africa, where historical inequalities continue to impact access to quality education.

The study by Sywelem (2024) underscores the necessity for collaboration among stakeholders to establish guidelines that ensure accountability and foster responsible AI implementation in education. Consequently, while AI holds significant potential to enhance educational services within South

African TVET colleges, it is imperative to address the challenges of overreliance and bias to ensure equitable benefits from these technologies for all students.

The above-mentioned limitations highlight the complexities involved in integrating digital technology into education for SDT, necessitating careful consideration and strategic planning to overcome challenges (Ajani and Dlomo, 2024).

3.4 Best Practices for implementing sustainable development strategies

3.4.1 Digital transformation in HEIs: lessons from smart cities

Building upon the concept of Smart Cities, Van der Hoogen, Fashoro, Calitz, and Luke (2024) investigate the role of DT as a tool for sustainable development within South African municipalities. In their study, Van der Hoogen et al. (2024) emphasise the foundational role of HEIs in cultivating the skills necessary for digital adoption within municipalities, aligning with sustainability objectives. They propose a DT framework specifically tailored to smart city initiatives, focusing on the application of digital technologies to enhance urban processes and achieve long-term sustainability goals. Although the primary context is municipalities in South Africa, insights into digital adoption, smart governance, environmental sustainability, and technology infrastructure are pertinent for HEIs considering SDT strategies. Thus, it addresses the research question of how lessons learned from digital adoption in the South African province of Eastern Cape Municipalities apply to other developing nations facing similar challenges in energy management and urban planning (Van der Hoogen et al., 2024). The aspect offers valuable information on the transferability of SDT strategies in different contexts, including HEIs in developing countries. The study highlights the potential of HEIs to contribute to skill development and collaborate with municipalities on sustainable urban planning initiatives that use digital technologies.

Van der Hoogen et al. (2024) do not offer a detailed discussion on how HEIs can implement DT strategies for SD in cities. However, it provides empirical insights into the DT framework for smart municipal digitalisation. Understanding the frameworks and principles of DT informs the development and implementation of similar strategies in HEIs to improve sustainability and efficiency.

Higher education institutions are increasingly focusing on utilising digital technologies to create positive environmental and social impacts. The research stream on financing and sustaining initiatives to develop environmental and social value is highly relevant (Bencsik, Palmié, Parida, Wincent, Gassmann, 2023). Applying a micro-foundation perspective, emphasising the aspect of individual

decision-making in shaping organisational outcomes targeting smart city initiatives in Switzerland. They consider how users' decisions to pay for a value proposition influence organisational value capture. The resultant framework of business models for digital sustainability, with its 12 theoretically possible business model types, offers a structured approach for HEIs to conceptualise and evaluate their SDT strategies regarding sustainability (Bencsik et al., 2023).

For higher education institutions undergoing SDT, a highly relevant research study is Komninos, Kakderi, Collado, Papadaki, and Panori (2022), which specifically focuses on urban DT strategies, identifying lessons learned and strategies adopted. As HEIs increasingly use digital technologies to improve teaching, learning, research, and administrative processes, insights from urban DT initiatives are valuable for informing strategies in this context. Sustainable digital transformation strategies must consider exacerbating existing inequalities in TVET colleges. These SDT strategies must ensure that all students benefit equally from technological advancements (Gkrimpizi, Peristeras and Magnisalis, 2023). Komninos et al. (2022) provide information on the design of DT strategies based on the experiences of cities participating in the Digital Cities Challenge initiative.

Through studying the strategies adopted by cities such as Sofia, Granada, and Kavala, researchers provide valuable lessons and best practices applicable to DT strategies in HEIs. Furthermore, the researchers listed common characteristics that shape the design of DT strategies, such as using digital platforms to open markets for e-services, improving local infrastructures, improving digital skills, and establishing innovation funding mechanisms. These standard features may guide HEIs seeking to develop effective SDT strategies. Komninos et al. (2022) emphasise the importance of creating digital platforms for ecosystem building, highlighting network effects and externalities in driving DT. Higher education institutions can learn from these insights to foster collaboration, innovation, and knowledge exchange within their digital ecosystems, which are essential for SDT. Although the focus is on urban contexts, the lessons learned from the Digital Cities Challenge initiative and the strategies developed by participating cities may be transferable to other settings, including HEIs. Analysing the applicability of these lessons to the higher education context can enrich the understanding of effective DT strategies.

Joyce and Javidroozi (2024) shed light on critical factors that hinder or facilitate effective DT initiatives by identifying barriers and prerequisites for cross-sectoral data sharing in smart cities. These insights can inform strategies to overcome obstacles and implement SDT strategies in HEIs. The primary focus of the study is on smart city development, the insights gained regarding cross-sector data sharing, technology integration, and navigating data protection regulations are highly relevant to the broader context of DT in HEIs (Joyce and Javidroozi, 2024). Higher education

institutions often face similar challenges related to data sharing, privacy regulations, and technological integration. They used a robust qualitative methodology in their study, including thematic analysis of interviews and framework development, to explore the multifaceted aspects of cross-sector data sharing within smart cities. Such methodological rigour ensures that the findings and proposed framework are grounded in empirical evidence and provide practical insights for addressing similar challenges in other contexts, including higher education. The credibility and robustness of the proposed approach, including validating the framework, are enhanced through additional interviews with smart city experts. The validation process ensures that the framework is applicable and effective in addressing the real-world challenges faced by urban planners and stakeholders, including those involved in higher education. The proposed framework can serve as a blueprint for HEIs seeking to navigate similar challenges and implement SDT strategies. Joyce and Javidroozi (2024) generally contribute to advancing the discourse on smart city development, providing valuable insights and practical guidance for balancing cross-sectoral data sharing with data protection regulations.

3.4.2 Emerging technologies reshaping educational experiences

As DT continues to evolve, the role of AI, Virtual Reality (VR) and AR in higher education is expected to grow. Institutions that embrace these technologies will likely enhance their competitiveness and appeal in the global educational landscape (Shenkoya and Kim, 2023). Digital tools, such as AI, play a pivotal role in personalising the educational journey for students. In analysing data on student performance and engagement, AI can help create customised learning pathways and adaptive learning environments, ensuring that educational content meets individual needs (Abulibdeh et al., 2024). Artificial Intelligence, AR, and VR are critical components of DT in higher education, offering innovative ways to enhance learning, personalise education, and engage students effectively. Institutions must strategically integrate these technologies to optimise their impact on educational outcomes.

Sviridova, Yastrebova, Bakirova, and Rebrina (2023) assert that immersive technologies can create engaging and interactive learning experiences. For example, medical students can practice surgeries in a virtual environment, or history students can take virtual tours of historical sites (Sviridova et al., 2023). ICT enables simulated experiments when physical resources are unavailable (Moosa et al., 2023). In post-COVID-19 Namibia, researchers discuss virtual learning environment principles and strategies (Cloete and Ndlovu, 2023). They focus on tourism education, with findings applicable to HEIs, including digital technologies such as VR and AR in enhancing tourism education. In alignment with the broader goals of SDT in higher education, insights on sustainability emphasise the need to

focus on both ecological and cultural sustainability. Focusing involves integrating sustainability principles into educational practices.

Furthermore, stable Internet connectivity, government support, and faculty development are among the challenges and opportunities associated with the DT in education. However, the potential of VR, AR, and online forums provides valuable examples to promote sustainable learning practices with a focus on tourism (Cloete and Ndlovu, 2023). These technologies and approaches can be adaptable to various disciplines within HEIs for sustainable education.

Vlizos et al. (2024) present an innovative methodology for using digital technologies in archaeological documentation and visualisation. Such methods are relevant to HEIs looking to integrate digital tools into teaching, research, and preservation efforts. The systematic approach proposed in the investigation could provide information on effective strategies for implementing DT initiatives in educational settings. Research primarily focuses on the preservation and enhancement of cultural heritage using digital technologies. The methodologies and technologies discussed, such as digital documentation, 3D scanning, and VR or AR, have implications for DT in higher education.

Higher education institutions often use similar technologies for educational purposes, immersive learning experiences, and research in archaeology, history, and cultural studies. Vlizos et al. (2024) highlight the impact of digital technologies on the sustainability, accessibility, education, and participation of cultural heritage. These themes are highly relevant to discussions around SDT in higher education. Higher education institutions strive to make educational resources and cultural heritage accessible to diverse audiences while minimising environmental impact, making the findings of Vlizos et al. (2024) relevant to the broader goals of HEIs. Researchers discuss practical applications of digital technologies, including developing a VR installation for public participation. Understanding how digital tools are applicable in real-world scenarios to improve educational experiences and public outreach may inform the development of SDT strategies in higher education.

Westergren et al. (2024) observe and evaluate an IoT implementation project over two years to explore its transformational potential. Successful IoT adoption requires proactive leadership and consideration of stakeholder perspectives. Initially, the project manager aimed to transform municipal facility management using IoT. The project aimed to shift from scheduled to need-based cleaning practices. The study involved the DT project - "Roomie", which aims to optimise cleaning operations in municipal buildings. The IoT system was developed by SysDev, with the municipality owning the data. A pilot project was launched and tested Roomie in a municipal townhouse with 30 sensor-equipped rooms. The IoT sensors monitored room status, occupancy, and air quality to inform data-driven cleaning decisions. Data collection for the Roomie project included observation and interviews

at participants' workplaces, ensuring anonymity and confidentiality. The findings were grounded in existing research to ensure both relevance and novelty. Findings include the assertion that Digital technologies, such as IoT, can cause profound disruptions in various sectors. The cleaners expressed concerns about the system's impact on their work practices. Furthermore, the cleaners felt excluded from initial project discussions, affecting their understanding. Yet, over time, cleaners began to view Roomie as a helpful app rather than a burden. The insights from the study provide a framework for South African TVET institutions to sustainably transform their digital strategies by leveraging IoT, engaging stakeholders, addressing cultural and ethical concerns, bridging knowledge gaps, and maintaining a long-term vision.

To maximise the benefits of these technologies, CPD for faculty is essential. In recognition of the fact that most South African students, especially from rural and township schools, have not acquired the necessary science concepts and skills to perform well in science. The South African government has put policies in place to address the poor learner performance in STEM subjects such as mathematics and science, with much hope being pinned on the role that technology could play in addressing the challenges faced (Moosa et al., 2023). According to Ajani and Dlomo (2024), educators need to be adept at using these tools to enhance their teaching practices and improve student learning experiences. The successful implementation of AI, AR, and VR requires a strategic approach that aligns with the institution's mission and educational goals. Institutions must consider the technological, pedagogical, and strategic dimensions to leverage these tools effectively. These technologies also serve to increase student engagement and motivation. In providing interactive and immersive experiences, students are more likely to be actively involved in their learning process, which can lead to improved educational outcomes. The integration of AR and VR into the curriculum allows educators to employ innovative teaching methods (Moosa et al., 2023). For instance, medical training programs using VR enable students to practice virtual surgeries, thereby enhancing their practical skills without the risks associated with real-life procedures.

Allowing, for instance, social worker students to engage in realistic scenarios, such as interacting with clients in a hospital setting, may enhance students' decision-making skills and build confidence in client communication. Neden (2022) discusses the application of VR technology to enhance real-world learning experiences in the education of social workers. While the focus is on the education of social workers, the principles and approaches described are relevant to various disciplines within higher education. Neden (2022) uses Backwards Design and a six-stage design thinking process for planning, targeting adult students with diverse abilities and prior technology experience. Scaffolding encompasses VR immersion, readings, and peer feedback to enhance skills. Students use VR headsets to access Apps and engage in hybrid learning.

In alignment with the focus on SDT strategies, the researcher emphasises developing a sustainable approach to real-world learning using VR technology, indicating a plan for integrating technology into HEIs in a sustainable manner. In addition, the researcher emphasises the importance of agility for innovation and understanding how technology enhances existing practices without significantly increasing costs. The aspects are important for HEIs looking to embark on DT journeys while ensuring sustainability. A study conducted by Neden (2022) uses the SATNAV approach, which is described as transferable to a wide range of contexts, indicating its applicability beyond the education of social workers. SATNAV minimises constraints in utilising virtuality technologies for education. The study emphasises a sustainable approach by focusing on low-cost and accessible resources. Assessment includes formative feedback and a summative portfolio submission. Furthermore, Neden (2022) provides valuable insights into the findings on the SATNAV approach, specifically highlighting its low-cost, accessible resources and integration with existing practices (Neden, 2022).

Incorporating game-like elements, such as leaderboards, digital badges, and rewards, into the learning process enhances student engagement and motivation. Digital badges and micro-credentials are digital representations of skills or knowledge that students have acquired. Often used in CPD and continuing education to recognise and validate learning outside traditional educational programs. The researchers Li and Chu (2021) examined the effectiveness and sustainability of gamified reading platforms in primary education in China. Although the primary focus is on primary education, the insights gained from the current study are highly relevant to understanding the effectiveness of gamification strategies in HEIs, especially for reading and competence among students. Li and Chu (2021) present empirical evidence examining the impact of an online gamified reading platform on students' academic performance, motivation, and reading abilities. The findings add value and provide insight based on research results. Among the three, one substudy explored the sustainability of the effects of the gamified platform over several semesters, offering a longitudinal perspective. Understanding the sustainability of gamification effects is important for HEIs looking to implement long-term DT strategies. Exploring gamification as a digital technology to enhance student motivation and learning outcomes supports the broader concept of using digital tools to improve educational experiences. Li and Chu (2021) offer implications for practice by highlighting the benefits of active participation with gamified reading platforms to improve reading interest, motivation, habits, and abilities. These implications can inform the design and implementation of SDT strategies in HEIs, particularly in fostering student engagement and improving learning outcomes.

The study by Liu et al. (2022) examined how digital technologies support the circular economy, a critical concept for sustainable practices. The researchers propose a framework to match digital functions with circular economy strategies. This framework offers valuable information for HEIs

considering SDT strategies, helping them identify suitable digital technologies to achieve their sustainability goals. While the research has a broader context, the framework's principles are adaptable to the specific needs of HEIs. The researchers Endres et al. (2020) focus on industrial firms, and the concept holds relevance for HEIs navigating the DT landscape. Through developing strong sensing capabilities, HEIs can identify emerging trends and adapt their educational offerings to stay competitive. The study also highlights the importance of diversifying knowledge sources relevant to HEIs. In addition to traditional methods, HEIs can leverage digital tools for market research, student data analysis, and industry trends tracking to gain valuable insight for strategic decision-making (Ajani and Dlomo, 2024; Meijer, 2024).

3.4.3 Frameworks for digital transformation in HEIs

Within HEIs, SDT strategies can extend beyond the institution's walls and contribute to broader societal goals like SD in rural areas. However, developing an ICT infrastructure that meets modern requirements pertinent to HEIs aims to enhance their digital capabilities. The role of HEIs in developing and delivering digital education programs tailored to the needs of rural communities highlights the importance of the institutional environment in facilitating SDT. This aspect is also important for HEIs operating within regulatory frameworks and institutional structures that influence their DT strategies. Higher education institutions often rely on a robust ICT infrastructure to support digital teaching, learning, and administrative processes (Moosa et al., 2023). Digital transformation in agriculture is an essential area of study for HEIs in agricultural education and research. Aivazidou and Tsolakis (2022) acknowledge the potential social challenges of adopting automated solutions in rural areas, such as unemployment. They propose human-robot synergistic systems as a socially viable alternative to address these challenges. However, their research does not directly address HEIs but focuses on agribusinesses and rural communities. Aivazidou and Tsolakis (2022) explore the challenges and opportunities associated with agricultural robots, emphasising the concept of human-robot collaboration as a pathway to SD in Greece.

Higher education institutions are striving to integrate emerging technologies to improve teaching, research, and operational efficiency (Gebresenbet, Bosona, Patterson, Persson, Fischer, Mandaluniz, Chirici, Zacepins, Komasilovs, Pitulac and Nasirahmadi, 2023). Lichtenthaler (2020) offers an excellent example of the importance of digital technologies, such as data analytics and AI, as potential tools for HEIs in SDT strategies. Integrating these technologies with human expertise is foundational for HEIs to maintain the value of educators in the learning process. The study acknowledges the limitations of the business focus and differentiation of these technologies in an educational setting. Gebresenbet et al. (2023) focus on smart and sustainable agricultural systems, the concepts, methodologies, and technologies discussed being highly relevant to DT strategies in HEIs, especially

those involved in agricultural or environmental studies. The study proposes a comprehensive concept for integrating various digital technologies, including data collection methodologies, AI, edge and cloud computing, blockchain, and decision support systems. Understanding how these technologies are integral in improving agricultural systems provides valuable information to HEIs seeking to leverage digital technologies for educational and research purposes (Truong, 2022). Moreover, Gebresenbet et al. (2023) propose increasing the agricultural sector's competitiveness, sustainability, and resilience. Higher education institutions increasingly focus on sustainability initiatives and prepare students to address environmental challenges. The insights of the current study can inform curriculum development, research agendas, and institutional strategies related to sustainability and resilience in higher education. Guide further investigations in both agricultural and educational contexts. The study identifies future research directions related to the proposed concept. Higher education researchers and practitioners can use these research directions to explore the application of digital technologies in their respective fields and contribute to advancing knowledge in SDT strategies.

Wang and Mei (2024) focus on the impact of digital economic growth on agricultural carbon dioxide emissions, with highly relevant findings for HEIs. The study findings, particularly regarding the reduction in agricultural carbon dioxide emissions associated with the evolution of the digital economy, may have implications for other sectors beyond agriculture. Higher education institutions can use these insights to explore how DT can contribute to sustainability goals in diverse fields, such as energy, transportation, and manufacturing, which are also relevant to their educational and research missions. Higher education institutions increasingly integrate digital technologies into their operations and curricula to promote sustainability across various sectors, including agriculture. Understanding the spatio-temporal effects of digital economic growth on agricultural carbon dioxide emissions informs HEIs' efforts to develop SDT strategies in agriculture-related disciplines and research. The study's recommendations have broader policy implications that extend to HEIs. These recommendations include accelerating the development of digital economy infrastructure, promoting the integration of digital technology with agriculture, and advocating for energy-efficient agricultural practices. Higher education institutions support SDT-related policy efforts by conducting research, providing expertise, and offering educational programs focused on digital innovation and sustainability. The approach by Wang and Mei (2024) combines insights from the digital economy, agriculture, and environmental sustainability, aligning with the interdisciplinary nature of many sustainability initiatives in HEIs. Through incorporating perspectives from multiple disciplines, HEIs can develop holistic approaches to SDT that address complex challenges across different sectors and domains.

Launched in 2005, the European Union Emissions Trading Scheme (EU-ETS) is the world's first and largest carbon trading system (Zhang et al., 2023). It was launched in 2005 and has been a significant driver of emissions reductions within the EU. Companies receive or buy emission allowances, which can be traded with each other as needed. The goal is to incentivise companies to reduce emissions and invest in cleaner technologies. Carbon trading is an emerging approach to environmental energy trading born under this system, and is a market mechanism to promote global reductions in greenhouse gas emissions. Zhang et al. (2023) examine how carbon emissions trading policies affect enterprise ESG (Environmental, Social, and Governance) performance, providing insights for sustainability initiatives. Higher education institutions may have different missions and functions compared to for-profit companies. Although the focus is on enterprises, the findings are highly relevant to the broader discussions about sustainability strategies, including those implemented in HEIs. These insights can inform policymakers and institutional leaders about effective strategies to promote sustainability through policy interventions. Moreover, Zhang et al. (2023) employ empirical data collected from Chinese A-share listed enterprises over a significant period (2011-2019) and use the difference-in-difference (DID) method for analysis. China, the largest emitter in the world, is responsible for about 30% of global carbon emissions.

In addition to causing severe environmental pollution, large amounts of carbon dioxide also impede the development of the Chinese economy (Lü, 2024; Wang and Mei, 2024). This rigorous approach provides valuable information on how carbon emissions trading policies affect enterprise ESG performance, thus contributing to understanding the effectiveness of similar sustainability initiatives in higher education. The study examines directly how carbon emissions trading policies affect enterprise ESG performance and explores the channel mechanism for this impact. Understanding how policies influence performance informs the design and implementation of SDT strategies in higher education. Enterprises with a high degree of DT show a more positive impact of carbon emission trading policy on ESG performance (Zhang et al., 2023). Evidence points out that trading policies of carbon dioxide emissions encourage enterprises to enhance their R&D investments and promote internal controls, leading to improved ESG performance. These insights have practical implications for organisations seeking to improve their sustainability practices, including HEIs undergoing DT. The study provides theoretical guidance to governments using carbon dioxide emissions trading to regulate businesses environmentally. Higher education institutions are instrumental in advancing sustainability practices and educating future leaders on environmental, social, and governance principles. The beneficial influence of DT on enterprise ESG performance highlights the function of digital technologies in promoting SD transformation in higher education institutions.

HEIs are critical in knowledge exchange and engagement with policymakers and stakeholders, particularly in conveying technical evidence to non-specialists. Buschke, Estreguil, Mancini, Mathieux, Eva, Battistella, and Peedell (2022) presented the Africa Knowledge Platform as a successful digital implementation case study for sustainability communication. The Africa Knowledge Platform employs digital storytelling and interactive tools to convey policy-relevant research concerning African raw materials. The Africa Knowledge Platform aligns with the broader theme of leveraging digital technologies for knowledge dissemination and engagement, which is relevant to SDT strategies in HEIs. Furthermore, the Africa Knowledge Platform frames its narratives within the context of international development agendas, such as the SDGs.

Hampton and Foley (2022) investigate the role of DT in retail electricity markets, emphasising the integration of analytical approaches, proprietary and open-source modelling tools, and development frameworks across data science, software development, cloud computing, and IoT. The interdisciplinary approach resonates with the multifaceted nature of SDT strategies in HEIs, which often require collaboration across various departments and disciplines. The authors highlight the challenges of data siloing, a critical consideration for HEIs seeking to integrate diverse digital technologies effectively. While the study's primary focus is on the electricity market, the emphasis on cross-disciplinary collaboration and the integration of various technologies offers valuable insights for HEIs developing their own DT strategies. Furthermore, while not directly focused on HEI operations, the study's focus on sustainable energy solutions aligns with the broader goal of integrating sustainability into DT initiatives within the higher education sector.

Institutions use platforms such as Moodle, Blackboard, and Canvas to manage course content, track student progress, and facilitate communication between students and instructors. Learning management systems platforms support blended and fully online learning environments (Holler et al., 2023; Dlamini et al., 2024). Using a mixed methods approach in Ghana, Asamoah (2019) investigated the use of learning management systems in HEI, focusing on student perceptions and the roles of lecturers and educational authorities. However, focusing on a particular LMS (Sakai or Moodle) and the context of Ghanaian HEIs may limit generalisability. Evidence points out that addressing student concerns and challenges related to digital learning tools is essential, highlighting the importance of faculty development programs to enhance technology-based teaching practices.

The digital learning landscape has continuously transformed for over a decade (Razak et al., 2023). The study investigates the transformation of digital learning (specifically, e-learning) in public schools, which aligns with the broader theme of DT in education. The researchers strive to provide a comprehensive analysis incorporating external and internal barriers and examine the prominent

theories for studying the successful integration of e-learning among educators. Reviewing data from 42 articles between 2010 and 2022 from Scopus databases, the study provided a thematic and theoretical understanding of digital learning transformation among public school educators. The researchers Razak et al. (2023) used a combination of content analysis and comparative analysis to examine the construction of the theme for the two research questions. A grounded-theory approach informed the analysis, allowing for inductive exploration and critique of the themes that emerged from the data. The exploration of barriers and enablers to DT is relevant for HEIs. Understanding these factors informs strategies for sustainable implementation. The findings include barriers and enablers and list Cultural-Historical Activity Theory (CHAT), Technological Pedagogical Content Knowledge (TPACK), Technology Acceptance Model (TAM), and Unified Theory of Acceptance and Use of Technology (UTAUT) as prominent theories used to conduct DT research. In addition, the study is limited to grades K-12, which differs from the higher education context. The researchers Razak et al. (2023) needs to address the sustainability aspect of DT.

Table 1: Summary of the theories mentioned by Razak et al. (2023)

Theory	**Developed By (Year)**	**Relevance to Sustainable Digital Transformation in HEIs**
Cultural-Historical Activity Theory (CHAT)	Lev Vygotsky (foundation), Alexei Leontiev, Yrjö Engeström (expansion) (1970s)	Cultural-Historical Activity Theory (CHAT) provides a comprehensive lens for understanding technology integration in education by focusing on the social and cultural dimensions of learning. Instead of viewing digital tools as neutral instruments, CHAT examines how technological adoption is deeply influenced by human interactions, cultural backgrounds, and institutional contexts. The theory explores learning through "activity systems", a framework that highlights the complex interactions between tools, individuals, and communities. In doing so, CHAT helps educational institutions understand that technology implementation is not only a technical process, but a socially embedded practice that requires careful

		consideration of diverse cultural and historical perspectives.
Technological Pedagogical Content Knowledge (TPACK)	Punya Mishra and Matthew Koehler (2006)	The Technological Pedagogical Content Knowledge (TPACK) framework offers a holistic approach to educational technology integration, recognising that effective teaching with digital tools requires more than only technical skills. It emphasises the critical interconnection between three key domains: technology, pedagogy, and content knowledge. At its core, TPACK suggests that successful educational technology implementation is not about simply adding digital tools to existing teaching methods, but about creating a sophisticated blend of technological, pedagogical, and subject-specific expertise. Ultimately, TPACK provides a robust blueprint for educators seeking to transform their teaching practices through intelligent and purposeful technology integration, ensuring that digital tools genuinely enhance rather than simply supplement educational content.
Technology Acceptance Model (TAM)	Fred Davis (1989)	The Technology Acceptance Model (TAM) provides a strategic framework for understanding how individuals perceive and adopt new technologies, particularly in higher education settings. At its core, TAM examines two critical psychological factors that influence technology adoption: perceived ease of use and perceived usefulness. The Technology Acceptance Model essentially transforms technology adoption from a technical challenge into a human-centred process, emphasising that successful DT depends on understanding and

		addressing the psychological and practical concerns of end-users.
Unified Theory of Acceptance and Use of Technology (UTAUT)	Viswanath Venkatesh et al. (2003)	The Unified Theory of Acceptance and Use of Technology (UTAUT) offers a comprehensive framework for understanding technology adoption in complex organisational environments like Higher Education Institutions. Unlike simpler models, UTAUT provides a multi-dimensional approach to predicting technological acceptance by integrating several key factors. Essentially, UTAUT transforms technology implementation from a technical challenge into a holistic, human-centred approach that respects the complex dynamics of institutional change.

While the theories mentioned in Table 1 offer critical insights into DT, Razak et al. (2023) overlook the sustainability aspect of DT. There is a need to integrate ecological, economic, and long-term viability considerations into existing frameworks to ensure that DT efforts in HEIs are not only effective but also enduring. Understanding these theories and their relevance to HEIs helps design holistic, actionable strategies for sustainable DT.

Digital modules serve as self-contained units of learning that teach specific skills or concepts, often incorporating multimedia elements like videos, interactive quizzes, and simulations. Digital modules also adopt online platforms for course delivery, content management, and communication. Research discussing barriers to the successful implementation of e-learning identifies various critical success factors (CSFs) alongside the barriers (Naveed et al., 2022). E-learning is a digital technology used in the educational setting of HEIs (Razak et al., 2023). Understanding these barriers is fundamental to integrating e-learning into educational practices effectively, a component of DT strategies that is highly relevant for HEIs undergoing DT. Critical success factors, alongside barriers, indicate a comprehensive analysis of the factors that influence the success of e-learning. Identifying CSFs is essential for designing SDT strategies in HEIs, as it assists in prioritising resources and efforts towards areas that contribute the most to success. However, the study focuses on barriers to successful implementation rather than on sustainable practices. The study highlights HEIs' barriers when

implementing DT strategies, such as e-learning. These barriers can impede sustainability efforts when not addressed. The researchers Naveed et al. (2022) use the Analytic Hierarchy Process Group Decision-making (AHP-GDM) methodology to assess barriers and CSF rigorously. The structured methodological approach systematically assesses and prioritises factors, providing valuable insights for decision-makers in HEIs. Identified barriers, such as those related to institutional management, infrastructure, students, and educators, are directly relevant to the DT efforts in higher education. Addressing these barriers is fundamental to ensuring the effectiveness and sustainability of digital initiatives, including e-learning implementations.

Kibrit, Altinay, Dagli, Altinay, Sharma, Shadiev, Tlili, Celebi, Jemni, and Bastas (2022) state that accessibility is a critical aspect in ensuring inclusivity and equity in education, which aligns with the broader goals of SDT. Ensuring all students have access to digital learning tools is important for inclusivity. Although Kibrit et al. (2022) focuses on vocational education training (VET) in Northern Cyprus, the principles of sustainability and accessibility are applicable at various levels of education, including HEI. The study evaluated accessibility strategies in VET, which is highly relevant to discussions of DT strategies in HEIs. The study adopted a qualitative approach, using semi-structured interviews and public reports for data collection. The methodological approach enabled an in-depth exploration of accessibility strategies and their effectiveness, providing valuable insights to inform DT strategies in higher education.

Kibrit et al. (2022) recommend defining appropriate roles and responsibilities, resolving financial issues, and overcoming inadequate educator training. These recommendations inform the development of SDT strategies in HEIs, particularly ensuring accessibility for all students. These practical recommendations are essential for successfully implementing SDT strategies in HEIs. The study primarily focuses on VET, but some accessibility insights apply to HEIs. At the higher education institutions, it is important to consider accessibility when designing digital learning environments and the need for sustainable strategies to ensure long-term access to digital resources for all students (Kibrit et al., 2022).

Ensuring equitable access to digital resources and opportunities is critical to promoting inclusivity and addressing disparities in health care (Clark, Maclachlan, Marshall, Morahan, Carroll, Hand, Boyle and O'Sullivan, 2022). Digital inclusion and connectivity are essential for SD, a critical aspect of DT in HEIs (Nosratabadi et al., 2023). Therefore, Clark et al. (2022) offer a conceptual framework (Just Digital Ethical Framework with the 18th SDG for Digital Connection), highlighting how digital equity is critical for successful SDT in HEIs. The conceptual framework that describes the strategic

drivers to achieve the SDGs through digital technologies provides a structured approach to analyse the effectiveness of DT strategies in HEIs.

Rodríguez-Abitia, Martínez-Pérez, Ramirez-Montoya, and Lopez-Caudana (2020) studied the use of technology in higher education for SD. The study directly addresses the adoption and application of technology in HEI, a central research theme on SDT strategies in HEIs. Rodríguez-Abitia et al. (2020) focus on integrating technology into teaching-learning processes, which aligns with the scope of research on strategies aimed at enhancing education through DT. The study investigates a critical aspect of SDT: how technology is applied within HEIs to achieve SD objectives. Rodríguez-Abitia et al. (2020) highlight the role of technology in achieving quality education, another significant aspect of SDT in HEIs. Through multidimensional analysis, it offers valuable insights into SDT strategies. Explore the technological, pedagogical, and organisational dimensions, providing a comprehensive understanding of the factors that influence the adoption and use of technology in HEIs. Including HEIs from both Spain and Mexico provides a cross-country perspective, allowing comparisons and identification of common challenges and effective strategies in DT. Furthermore, the research emphasises the importance of contextual factors in successfully implementing technology, a fundamental consideration for SDT.

In the context of DT strategies in HEIs, it is essential to comprehend the dynamics of digital entrepreneurship, as these dynamics provide insights into how digital technologies intersect with entrepreneurship and contribute to SD (Herman, 2022). The study explored the impact of digital entrepreneurship on achieving the SDGs, particularly SDG 8 (Decent Work and Economic Growth) and SDG 9 (Industry, Innovation and Infrastructure). These SDGs are highly relevant to HEIs seeking to integrate SD principles into their DT strategies. The researcher Herman (2022) uses correlation and regression analysis, principal component analysis, and cluster analysis to examine the relationships between digital entrepreneurship, digitalisation, economic development, national competitiveness, and the achievement of the SDGs in European Union countries. The empirical findings provide valuable information on the complex interplay between these factors, which offers practical implications for policymakers and stakeholders in higher education. The study guides policymakers on implementing specific measures to promote digital entrepreneurship by highlighting European Union countries' differences and standard features regarding digital entrepreneurship and its impact on SD. These insights can inform the development of policies and strategies to promote SDT in HEIs. The research does not explore how HEIs can promote digital entrepreneurship. Research focuses on digital entrepreneurship at a national economic level, not within the context of HEIs.

The researchers Van Der Graaf et al. (2023) address an essential aspect of promoting effective learning strategies within HEIs by focusing on scaffolding self-regulated learning (SRL) among HEI students. The scaffolding SRL study examines the design and evaluation of digital scaffolds to support SRL, thus contributing to the ongoing discourse on DT strategies in higher education, as it explores the potential use of technology to improve learning processes. It emphasises the importance of SRL for sustainable education, as it leads to better academic achievement and lifelong learning. The study contributes to developing sustainable learning practices in HEI by investigating how digital scaffolds can improve SRL. The study provides evidence from a pre-posttest design on the effectiveness of personalised scaffolds based on real-time detection of SRL, improving student learning outcomes. These findings inform future interventions and DT strategies in HEIs to support student learning. The focus on SRL in a learning environment connects to sustainable education, a goal for HEIs, as it equips students with long-term learning skills. It also focuses on a specific intervention (personalised scaffolds) to support SRL. It does not focus on the broader DT strategies of a HEI. The findings on personalised learning contribute to SDT strategies in HEIs that aim to improve learning outcomes.

Bechtsis, Tsolakis, Iakovou, and Vlachos (2021) discuss the importance of data-driven digital technologies for supply chain management, which aligns with the broader theme of SDT. Applying similar digital technologies and data-driven approaches can benefit the operations of HEIs. The role of data-driven technologies in supply chain management emphasises the importance of considering security, resilience, and sustainability (Bechtsis et al., 2021). The researchers offer a broader focus, highlighting the importance of data-driven approaches for SDT across various sectors, including HEIs (Bechtsis et al., 2021). The study needs to explore how HEIs can implement these strategies. The proposed generalised Framework for Resilience in the study serves as a model for TVET colleges to develop their own strategies for resilience and sustainability. In accepting similar frameworks, these institutions can better prepare for disruptions and enhance their operational effectiveness. It is highly relevant for South African TVET colleges, as they seek to modernise their operations and curricula to meet the demands of a rapidly changing job market. The importance of data sharing and collaboration highlighted in the paper aligns with the need for TVET colleges to engage with industry partners and stakeholders. Collaboration can facilitate the sharing of resources and information, which is important for developing relevant training programs that meet industry needs. The integration of digital technologies, such as AI and Blockchain, can inform curriculum development at TVET colleges. In equipping students with skills in these areas, colleges can enhance employability and prepare graduates for the demands of modern industries. The validation of the Framework for Resilience through real-world case studies, such as the organic food supply chain, demonstrates the

practical applicability of the research findings. From this framework, TVET colleges can draw parallels from these case studies to implement their own sustainable practices and DT initiatives.

Particularly relevant to HEIs with initiatives in sustainable procurement is research that illustrates the potential of digital technologies, such as blockchain, to promote sustainable practices in supply chains (Truong, 2022). The researchers Sarfraz, Khawaja, Han, Ariza-Montes, and Arjona-Fuentes (2023) examine the influence of sustainable supply chain strategy (SSCS) on sustainable competitive advantage (SCA) with a focus on the mediating role of blockchain technology (BCT) adoption and the moderating role of DT and sustainable supply chain practices (SSCP). Although the context is the hotel and resort industry, SSCS, BCT adoption, DT, and SSCP are highly relevant to DT strategies in HEIs. The study employs a quantitative approach and tests the proposed model using a sample of 331 hotel and resort managers. The concept of an SSC indirectly connects to HEIs' efforts to implement sustainable procurement practices. Empirical testing enhances the credibility of the findings and provides valuable insights into the relationships between SSCS, BCT adoption, DT, SSCP, and SCA. The researchers identified the mediating role of BCT adoption in the relationship between SSCS and SCA.

Sarfraz et al. (2023) examine how DT influences the relationship between SSCS and BCT adoption, and how SSCP affects the relationship between BCT adoption and SCA. However, it has limitations, including its focus on a specific industry (hospitality) and the narrower definition of sustainability. Understanding these mediating and moderating effects is fundamental to understanding the complex dynamics of SDT strategies (Sarfraz et al., 2023). The study's findings have significant implications for both theory and practice. These findings provide strategic insights for organisations, including HEIs, seeking to improve their competitive position through sustainable strategies and technologies. Understanding how SSCS, BCT adoption, DT, and SSCP interact to influence SCA informs the development and implementation of effective DT strategies in higher education. The sustainability aspect is a competitive advantage, not the broader environmental, social, or economic sustainability typically associated with HEIs.

HEIs often undergo DT initiatives, and understanding how digital technologies impact supply chain sustainability provides valuable information for implementing similar strategies in educational settings (Kunkel, Matthess, Xue and Beier, 2022). Accordingly, Kunkel et al. (2022) explored the role of digitalisation, particularly in the context of Industry 4.0, in supply chain management, a fundamental aspect of DT strategies. The study specifically focuses on environmental sustainability aspects within supply chain collaboration (SCC) and how firms collaborate on sustainability in the supply chain (Sellitto, Hermann, Blezs Jr and Barbosa-Póvoa, 2019). The environmental

sustainability aspects within the SCC include environmental data analysis and energy use. Sustainable practices are a critical component of DT strategies in HEIs, making the current study highly relevant.

The study by Kunkel et al. (2022) employs qualitative methods, including 18 interviews with industry representatives from international electronics buying firms and Chinese suppliers. Exploring the current use of digital technologies in SCC and their implications for sustainability. Including empirical evidence and insights from real-world practices can enrich the current study by providing concrete examples and case studies that enhance its understanding. Kunkel et al. (2022) provides policy and managerial levers to enhance the supply chain's socioecological performance, informing decision-making and strategy development in HEIs to improve sustainability through DT. Moreover, Kunkel et al. (2022) directly address opportunities (e.g., big data for energy management) and challenges (e.g., data-sharing concerns) associated with digitalisation for sustainable SCC. Although the research targets electronics firms in a business-to-business (B2B) context, this may differ from that of HEIs. However, the study highlights, for example, the role of big data in sustainability management, its challenges (such as data sharing), and the use of digital technologies for sustainable practices. Understanding these dynamics is important for HEIs considering SDT strategies, even if specific recommendations may need adaptation for the higher education landscape.

3.5 Chapter summary

This chapter focused on the multifaceted issue of SDT in HEIs. Sustainable digital transformation strategies in South African TVET colleges involve integrating technology to enhance educational outcomes, address socio-economic challenges, and align with global educational trends. The transformation is fundamental for preparing students for the demands of the 4IR and ensuring equitable access to quality education.

Inadequate infrastructure poses a significant barrier to SDT in South African higher education institutions. High data costs and limited access to reliable Internet services continue to impede students' engagement with digital learning platforms. Despite these challenges, opportunities for innovation and improvement exist within the digital education landscape, necessitating a proactive approach from stakeholders.

Recent studies emphasise the need for a multifaceted strategy to address these barriers. For instance, the digital revolution requires a fundamental redesign of curricula to integrate digital literacy and critical thinking skills. Tailored strategies that consider the socio-economic and cultural contexts of HEIs, particularly in developing countries, are equally critical. Additionally, effective adoption of digital technologies necessitates comprehensive training and ongoing support for educators.

Partnerships with industry further provide valuable insights into evolving job market trends, enabling HEIs to align their offerings with workforce demands.

Addressing these challenges is essential for fostering an environment conducive to successful DT. Institutions must adopt comprehensive strategies that not only address resistance and resource constraints but also cultivate a culture of innovation and adaptability among staff and students. This approach positions HEIs to harness digital technologies effectively, thereby improving educational outcomes and advancing sustainability objectives.

While significant barriers such as the digital divide and resource limitations persist, strategic investments in infrastructure, curriculum development, and industry collaboration can drive meaningful transformation. Future initiatives should prioritise equitable access to digital resources and promote innovative pedagogical practices to prepare students for the demands of a rapidly evolving job market.

Research further highlights the importance of employee acceptance and utilisation of new technologies, as evidenced by studies in microfinance institutions. Similarly, gamified approaches have been shown to enhance student participation and learning outcomes. Although primarily focused on primary education, these findings provide insights into strategies that may be adapted for use in HEIs, acknowledging the unique contexts and challenges they face.

HEIs should adopt a culture of continuous improvement, regularly seeking feedback from students and faculty to refine digital tools and teaching methods. The iterative process can lead to more effective educational practices and better student outcomes.

The next chapter reviews the underpinning theories and provides the conceptual research framework for SDT in South African HEIs.

Chapter Four: Underpinning Theories and the Conceptual Research Framework for SDT in South African HEIs

4.1 Introduction

The preceding chapters reviewed related works and literature that gave a foundation for the present study. Chapter Four discusses theories and frameworks that underpin the study and form the basis for the conceptual research framework that guided the present study. The approach includes using the Sustainable Information Systems (SIS) theory together with frameworks such as TOE, RBT, TBL, and Institutional Theory to assess internal resources, external pressures, and the overall impact of digital strategies. The underpinning theories were selected based on their significance towards the study objectives.

Evaluating and understanding the sustainability of DT strategies in South African TVET institutions requires a comprehensive and multi-dimensional approach, considering the unique challenges and opportunities in the context of education, technology, and sustainability (Nkalane, 2018; Nkala, Madikizela-Madiya and Ngundu, 2024). Sustainable digital transformation is not only concerned with using new technologies but also with creating sustainable added value in society. Despite the increased attention to DT, a shared understanding of exactly what DT encompasses and how a DT initiative is defined and led is still underdeveloped (Fantaye, 2019; Elia et al., 2024).

The chapter is structured as follows: Section 4.1 introduces the chapter, with Section 4.2 explaining the Information Systems theory of Sustainability. Section 4.3 deals with supporting theoretical foundations, and Section 4.4 highlights related practical metrics and tools. Section 4.5 presents the conceptual framework for evaluating the sustainability of digital strategies in TVET colleges. Section 4.6 discusses implemented initiatives and strategy, followed by Section 4.7, which summarises the chapter.

Table 4.1: Summary table of theories underpinning the present study

Theory	**Role in DT**	**Metrics or Indicators**	**SDG Alignment**
SIS theory	Integrates IS design with sustainability principles, focusing on systemic outcomes.	Energy consumption, social transparency, user	SDG 9, SDG 12, SDG 13

		satisfaction, and error reduction	
IS theory	Analyses how IS enable sustainability through resource optimisation and stakeholder engagement.	Stakeholder gap reduction, institutional structure merging, behaviour modification	SDG 8, SDG 9, SDG 12
Systems Theory	Models DT as interconnected socio-technical systems requiring holistic alignment.	Resource optimisation, adaptability, innovation acceleration	SDG 9, SDG 17
Organisational Change	Guides human-centric transitions during DT using structured change processes.	Employee adoption rates, leadership effectiveness, change readiness	SDG 8, SDG 9
Innovation Diffusion Theory	Explains adoption patterns and barriers to digital innovations.	Rate of adoption, compatibility assessments, relative advantage	SDG 9
Representation Theory	Analyses task-system dependencies and semantic complexity in digital work design.	Learning effort, task completion times, error rates	SDG 4, SDG 8
TOE	Analyses barriers (infrastructure, funding) and enablers (cloud tech, PPPs).		SDG 4, SDG 9, SDG 13
RBT or RBV	Guides resource allocation and competency gaps, for	Budget allocation for IT, staff training	SDG 8, SDG 12

	example, funding for devices, lecturer training.	participation rates (Modiba and Kekwaletswe, 2020; BMR and GIZ, 2022).	
TBL	Balances social equity, environmental impact, and financial viability.	Digital skills audits, carbon footprint reduction, ROI on ICT investments (BMR and GIZ, 2022; Stedman and Gillis, 2024).	
Institutional Theory	Analyses policy coherence and institutional resistance.	Alignment with DHET mandates, stakeholder collaboration (Modiba and Kekwaletswe, 2020; BMR and GIZ, 2022).	
TDA	Designs adaptive implementation roadmaps.	DXRI scores, phased adoption of AI or IoT technologies (Tustin and van Aardt, 2022; Hussein, Ramly, Ahmad, Ridzuan, Salehen and Dang, 2024).	

To effectively evaluate and assess the sustainability of DT strategies in South African TVET colleges, a multi-theoretical approach was deemed appropriate. The approach includes triangulating frameworks such as TOE, RBT, TBL, and Institutional Theory to assess internal resources, external pressures, and the overall impact of digital strategies. An integrated approach balances theoretical rigour with actionable insights, addressing South Africa's unique challenges while fostering equitable, resource-efficient DT.

South African TVET institutions are uniquely positioned to enhance their sustainability efforts and operational efficiency through the strategic implementation of Information Systems tools. Through adopting a data-driven approach, these institutions can optimise resource use and align with national directives for promoting green campuses and cost-effective operations. Specifically, IS tools, such as student management systems, learning analytics platforms, and facility monitoring systems, enable TVET institutions to make informed decisions that yield tangible environmental and economic benefits. For instance, DT for paper reduction, energy management, monitoring, and streamlined sustainable procurement.

The Bureau of Market Research (BMR) at the University of South Africa (Unisa) and Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) report assess the readiness of 50 TVET colleges in South Africa (BMR and GIZ, 2022; Tustin and van Aardt, 2022). The BMR and GIZ report involves capturing a baseline snapshot of DT readiness using 2022 data. The snapshot of the report helps in understanding the starting point of TVET colleges in terms of digital infrastructure, policies, skills, and sustainability integration. Providing data-driven insights to guide the development of a sustainable DT strategy. Sustainability in the present study involved a multi-year impact window to assess whether DT efforts translate into measurable improvements, which allowed monitoring trends, measuring progress, and adjusting strategies based on real-world implementation outcomes. KPIs were analysed over time to ensure that digital initiatives align with sustainability and long-term digital maturity goals.

Strategies should promote beneficial attributes in the economy, the environment, and society as a whole (Martínez-Pérez et al., 2022). Furthermore, Neumeyer and Liu (2021) provides the founding elements required to manage the fragmented DT. This chapter presents a structured way to approach this assessment, integrating multiple aspects of sustainability (economic, social, and environmental) and the relevant DT underpinning theories.

4.2 Sustainable Information Systems theory

Sustainable Information Systems theory entails how information systems can support and enhance sustainable development. This theory is also known as Information Systems; however, for the benefit of the study, the present study refers to it as the SIS theory. It reorients traditional IS design to prioritise environmental, social, and knowledge-centric sustainability. The theory integrates adaptability, stakeholder engagement, and knowledge management to align systems with ecological and societal needs (Seidel, Bharati, Fridgen, Watson, Albizri and Boudreau, 2017; Recker, 2023). The aim is to validate the framework through a case study and refine metrics for broader adoption as the theory shifts from efficiency-focused models to systems that actively reduce ecological harm while enhancing societal resilience (Maruster, Faber and Peters, 2008; Mustaquim and Nyström, 2014; Recker, 2023). SIS theory posits that Information Systems are not merely operational support functions, but rather have evolved to become fundamental, strategic drivers of sustainability within modern institutions. Therefore, SIS theory offers a powerful lens through which to understand and evaluate DT efforts in the context of South African HEIs.

4.2.1 Alignment with key sustainability dimensions in HEIs

At its core, SIS theory reminded the present study that ISs shape how institutions use digital technologies to foster ecological responsibility, social equity, and knowledge resilience in the face of rapid technological change (Maruster et al., 2008; Mustaquim and Nyström, 2014; Recker, 2023).

4.2.1.1 Environmental sustainability

SIS theory places a strong emphasis on reducing environmental harm by encouraging institutions to think critically about how their technologies are designed, deployed, and disposed of. In African HEIs, this is increasingly visible in the adoption of energy-efficient systems, solar-powered infrastructures, and smart waste management (Trevisan, Eustachio, Dias, Filho and Pedrozo, 2023; Genga and Babalola, 2025). The use of solar power and digital waste management exemplifies a commitment to sustainability in digital campus environments, a principle that aligns with the ecological focus of SIS theory.

4.2.1.2 Social sustainability

SIS theory emphasises equity, access, and inclusive engagement among stakeholders, notably in the South African context, where there are disparities in digital access and uneven resource distribution. SIS theory calls for equity and inclusion as pertinent (Gachie and Penceliah, 2016; Strapchuk, Koniordos and Strapchuk, 2025). That is, SIS theory encourages institutions to bridge the digital divide by ensuring all students and staff, regardless of location or socio-economic background, can engage meaningfully with digital tools. As studies show, inclusive digital platforms enhance not only

education delivery, but also social cohesion and long-term community resilience (Gachie and Penceliah, 2016; Trevisan et al., 2023; Strapchuk et al., 2025).

4.2.1.3 Knowledge-centric sustainability

A further key tenet of SIS is championing the idea that SDT must go beyond hardware and infrastructure, that it must be knowledge-driven. The principle of promoting knowledge generation and long-term adaptability. Studies Klishi (2023) and Trevisan et al. (2023) advocate for the embedding of sustainability literacy and digital competencies into the curriculum, supporting this view, to ensure future graduates are not only technically competent but also capable of responding to broader global challenges like the SDGs. In doing so, SIS theory complements initiatives that seek to produce future-ready graduates capable of advancing the SDGs and participating meaningfully in a digitally driven economy.

4.2.2 Designing sustainable information systems

The theoretical framework for SIS design is underpinned by principles aimed at fostering ecological responsibility and social equity within information technology. Key among these are:

4.2.2.1 Green IT practices

The SIS theory advocates for a lifecycle approach to managing technology, one that considers environmental impacts from manufacture to disposal. The principle mandates the adoption of strategies that comprehensively minimise the environmental footprint of IT throughout its entire lifecycle. Including, but not limited to, minimising energy use during system operation, preventing e-waste (Hilty, Seifert and Treibert, 2005; Recker, 2023). As well as adopting green procurement practices that address the broader lifecycle environmental impacts associated with the production, use, and disposal of information systems. The objective is to ensure that technological advancements do not inadvertently exacerbate ecological degradation. While both Green IT and Green IS contribute to environmental responsibility, their scopes and primary objectives differ remarkably. Green IT primarily centres on minimising the direct environmental footprint of the information technology infrastructure itself. Conversely, Green IS encompasses a far broader and more transformative scope. Importantly, it draws a distinction between Green IT, which focuses on reducing the direct environmental footprint of IT infrastructure, and Green IS, which uses systems to drive sustainability across all institutional operations.

4.2.2.2 Participatory design

Another cornerstone of SIS is the principle of participatory design, which encourages collaboration and engagement from a diverse range of stakeholders. Involving the active incorporation of the perspectives and insights of diverse groups, such as Campus, MIS, and ICT managers, as well as

Senior lecturers, into the decision-making processes pertaining to SIS development and implementation (Maruster et al., 2008; Recker, 2023). The collaborative approach systematically identifies and mitigates the potential for inadvertently shifting environmental or social burdens onto vulnerable communities, a phenomenon known as “offloading”. The phenomenon where the environmental or social costs of an information system are externalised or shifted to other ecological or social systems, often disproportionately affecting vulnerable populations or environments (Maruster et al., 2008; Recker, 2023). Through fostering broad participation, SIS designs ensure more ethically sound and context-aware digital solutions. Resulting in more effectively anticipated and internalised such costs, leading to more genuinely sustainable outcomes.

4.2.3 Metrics and evaluation principles

In the realm of SIS theory, robust metrics and evaluation principles are key for assessing the true sustainability of IT initiatives. Two foundational principles guide this assessment:

4.2.3.1 Life Cycle Assessment (LCA)

Life Cycle Assessment (LCA) principle advocates for a comprehensive, systematic evaluation of the environmental impacts associated with an information system across its entire life (Hilty et al., 2005; Seidel et al., 2017). Through LCA, the SIS theory is able to look at the full environmental cost of technology to avoid creating hidden environmental impacts (Seidel et al., 2017). The LCA means meticulously analysing the environmental footprint from the initial stages of production, for example, raw material extraction, manufacturing of hardware and software, and through its phases of use, for example, energy consumption, operational emissions, and finally to its disposal, for example, recycling, waste management of e-waste. The goal of LCA is to quantify and understand all potential ecological burdens, ensuring that sustainability efforts are holistic and do not merely shift environmental problems from one stage or area to another.

4.2.3.2 Triple Bottom Line (TBL)

Triple Bottom Line principle reinforces the need to assess digital initiatives not just on financial grounds, but also in terms of their social and environmental outcomes (Mustaquim and Nyström, 2014; Philbin, Viswanathan and Telukdarie, 2022). The framework necessitates that decisions regarding information systems are not solely driven by financial profitability but also by their positive or negative impacts on people (social equity) and the planet (environmental health). In addition to integrating these three "bottom lines", the TBL principle encourages a more holistic and responsible approach to SIS development and operation, aiming to create long-term value that benefits all stakeholders and ecosystems. Through integrating IS into strategic planning and operations, as well as aligning with DHET’s priorities of improved institutional performance while ensuring inclusivity

and sustainability. For South African TVET institutions, this could mean promoting environmental sustainability, for example, smart technologies, and ensuring economic efficiency, for example, reducing operational costs through automation, and supporting social equity, for example, improving access to education via digital platforms in rural and underserved areas.

4.2.4 Addressing challenges in South African HEIs through SIS theoretical lens

The SIS theory is a robust framework to navigate the distinct challenges faced by South African HEIs, focusing on policy and governance, infrastructure and resource allocation, and cultural and institutional resistance.

4.2.4.1 Policy and governance gaps

Despite the growing importance of DT, many HEIs still lack cohesive sustainability policies (Gachie and Penceliah, 2016). The SIS theory provides a guiding structure to integrate digital and sustainability goals into institutional digital strategies, thereby supporting alignment with national priorities such as the DHET Strategic Plan and the National Development Plan 2030 (Gachie and Penceliah, 2016).

4.2.4.2 Infrastructure and resource constraints

Infrastructure deficiencies, such as unreliable Internet access and funding shortfalls, are significant barriers to transformation (Trevisan et al., 2023; Genga and Babalola, 2025). The SIS theory advocates a participatory and needs-based approach to system design, ensuring solutions are both equitable and practical (context-sensitive), which is especially critical in historically disadvantaged institutions (Trevisan et al., 2023; Genga and Babalola, 2025).

4.2.4.3 Cultural and institutional resistance

Strapchuk et al. (2025) claim that resistance to digital innovation stems from outdated curricula practices or a lack of buy-in from staff due to low staff engagement, thus impeding transformation. The SIS theory advocates for strong leadership and inclusive planning processes, reframing ISs as enablers of institutional change to foster a culture of innovation through active stakeholder involvement and strategic digital planning.

4.2.5 Methodological relevance of SIS theory for qualitative research

4.2.5.1 Thematic analysis

In a qualitative evaluation, SIS theory provides a coding framework for analysing data gathered from stakeholders. The three sustainability dimensions, environmental, social, and knowledge, are well-suited to the structured coding process, offering categories that reflect participants' real concerns and

aspirations (Klishi, 2023; Trevisan et al., 2023). Themes such as ‘alignment with SDGs’, ‘digital inclusion’, and ‘collaborative governance’ can be readily mapped onto these pillars, facilitating coherent analysis and interpretation.

4.2.5.2 Case study design

For case study design, SIS theory’s systems-oriented perspective supports the use of case studies to evaluate institutional practices and transformation trajectories. Furthermore, the theory aligns with systems thinking approaches that seek to understand how different institutional elements interact and evolve over time (Klishi, 2023). It supports policy-relevant insights by encouraging the use of practical metrics and evidence to shape implementation strategies (Strapchuk et al., 2025). Through the value of systems thinking in sustainability assessments, SIS is, thus, affirmed as an appropriate theoretical lens for evaluating the governance and equity impacts of digital strategies within HEIs (Klishi, 2023).

4.2.6 Strategic Alignment

The SIS theory aligns with national and continental priorities, including broader development goals. The SIS theory inherently supports several United Nations SDGs, in particular SDG 4 (quality education) and SDG 9 (industry, innovation, and infrastructure). It achieves this by promoting inclusive access, innovation, and environmental consciousness in digital practices (Trevisan et al., 2023; Genga and Babalola, 2025). Moreover, this SIS theory aligns with South Africa’s National Digital and Future Skills Strategy. Through advancing digital literacy and equitable access to technology, the theory contributes to employability and poverty reduction (Gachie and Penceliah, 2016). Finally, the theory’s adaptability principle addresses systemic weaknesses such as governance inefficiencies and unstable funding models. The theory provides pathways for long-term resilience in institutional digital initiatives, encouraging adaptable, long-term digital planning and governance frameworks (Gachie and Penceliah, 2016; Strapchuk et al., 2025).

Sustainable digital transformation in South African HEIs should be grounded in several theoretical frameworks that address technological integration, systemic change, and socio-economic equity. These theories may provide structural guidance for addressing challenges such as infrastructure gaps, digital divides, and institutional resistance, while fostering inclusive growth. Garzoni, Turi, Secundo and Del Vecchio (2020) argue that DT is contingent upon an institution’s commitment to embracing and integrating digital technologies. The applications of SIS in TVET institutions may directly contribute to the national imperative of developing green campuses and ensuring cost-effective operations, demonstrating a commitment to both environmental stewardship and fiscal responsibility.

To succeed with these applications, strategic interventions are essential. These include developing policies centred on diversity, equity, and inclusion (DEI), investing in scalable Information Technology (IT) infrastructure, and integrating circular economy principles to optimise digital resource management (Mohamed Hashim et al., 2022b; Genga and Babalola, 2025). However, there exists a counter-argument that theory types, Analysis and Explanation, are not necessarily theories (Gregor, 2006).

4.3 Supporting Theoretical Foundations

In South African TVET institutions, the effective use of Information Systems may enable more sustainable institutional practices, curriculum innovation, and the holistic integration of environmental, economic, and social goals. This may not only contribute to internal efficiency and educational quality but also aligns TVETs with national development priorities and the global Sustainable Development Agenda.

4.3.1 The Triple Bottom Line theory

Triple Bottom Line theory is deemed applicable to assessing and evaluating the sustainability of DT strategies in TVET colleges across its three key dimensions. The Economic Dimension assesses whether DT strategies lead to increased operational efficiency, reduced costs, for example, paper, administrative overheads, and whether they open new revenue streams, for example, online courses. The Social dimension evaluates the impact of DT on student learning experiences, including inclusion, such as digital access for marginalised groups, and overall social equity in education. Whether the current strategies improve access to education, especially in rural or underserved areas. Finally, the environmental dimension assesses the ecological footprint of DT efforts. This includes measuring reductions in resource consumption, such as paper and energy usage, and evaluating whether green technologies are being adopted, for example, energy-efficient data centres.

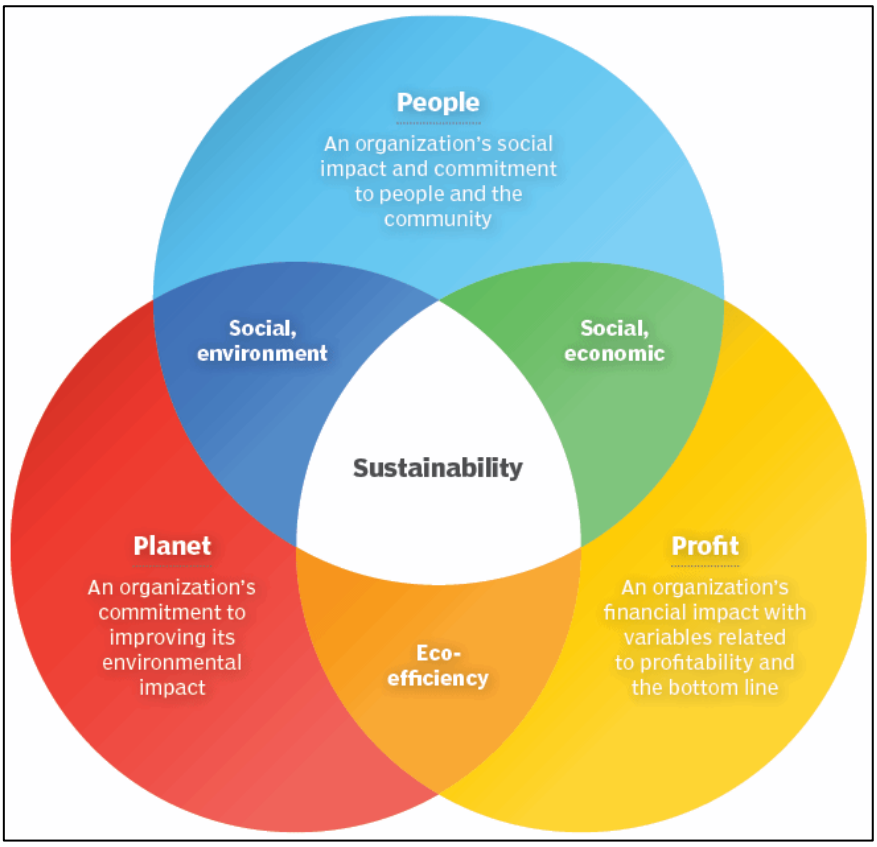


Figure 4.1: The triple bottom line framework's three Ps (Stedman and Gillis, 2024)

Figure 4.1 illustrates how the TBL theory (Elkington, 1998) offers a valuable framework for evaluating the sustainability of DT strategies in the context of South African public TVET colleges. The figure recognises the interconnectedness of economic, ecological, and social dimensions. The theory was coined in 1994 by John Elkington, a British author and business consultant who focuses on sustainability issues (Stedman and Gillis, 2024). The TBL's focus on people, planet, and profit aligns with the need to balance socio-economic equity, environmental sustainability, and financial viability in DT strategies. In the context of DT, this theory offers a comprehensive framework for evaluating whether transformation strategies align with long-term sustainability goals across these three dimensions. The TBL is an important component of sustainability efforts in many institutions (Stedman and Gillis, 2024). It points toward a more sustainable future for the climate, at least to the degree that it drives changes in institutions.

TBL offers opportunities for institutions to generate revenue and profits, such as attracting new students and staff who want to lessen their own impact on the environment, together with a healthier work environment for all employees and an improved standing in surrounding communities (Stedman and Gillis, 2024). It has been reported that institutions using TBL also gain tangible business benefits, such as lower energy consumption and costs, plus reduced CO2 emissions and carbon (Mohamed

Hashim et al., 2022b). Additional advantages include higher employee retention rates and an increased ability to attract new hires, as well as enhanced brand perception and reputation that can lead to higher enrolment rates. Opportunities for sustainable development within educational frameworks can be realised through TBL-aligned partnerships, notably industry collaborations designed to foster skills development (Tustin and van Aardt, 2022; Hussein et al., 2024).

In the present study, TVET colleges are provided with TBL guides for evaluating how DT strategies impact not only operational efficiency and cost-effectiveness (economic), but also their social implications, for example, student access and inclusion, and environmental concerns, reducing paper usage and energy efficiency. Key TBL metrics for the economic dimension include ROI of digital tools, energy efficiency, and Wi-Fi adoption rates (Mohamed Hashim et al., 2022b; Tustin and van Aardt, 2022). The key TBL metrics for the environmental dimension include E-waste reduction, cloud migration, and carbon footprint tracking (Mohamed Hashim et al., 2022b; Tustin and van Aardt, 2022). For the social dimension, the key TBL metrics are Digital literacy assessments, student retention rates, and equitable access (Tustin and van Aardt, 2022; Ajani, 2024). Hussein et al. (2024) assessed whether digital strategies are supporting the broader sustainability goals of colleges.

The BMR and GIZ (2022) report highlights low digital maturity and skills gaps in South African TVET colleges, necessitating a TBL-aligned strategy to balance equity, sustainability, and economic outcomes (BMR and GIZ, 2022; Tustin and van Aardt, 2022). The TBL addresses digital skills gaps among staff and students and equitable access to 4IR tools in under-resourced TVET colleges (BMR and GIZ, 2022; Tustin and van Aardt, 2022). It supports green IT practices, for example, energy-efficient infrastructure, and reduces carbon footprints (Stedman and Gillis, 2024). Furthermore, the reports evaluate the cost-effectiveness of digital investments, such as cybersecurity and ICT tools, while ensuring long-term institutional viability (Modiba and Kekwaletswe, 2020; Tustin and van Aardt, 2022). For institutions, the pervasive adoption of digital technologies may compromise the security of institutional data and stakeholder privacy, leading to inappropriate access to data or digital fraud (Elia et al., 2024).

It is challenging to quantify the people and planet bottom lines to the same level as the profit bottom line (Stedman and Gillis, 2024). According to Elkington (2018), a common limitation is that numerous decision-makers and managers within institutions worldwide tend not to pay attention to all three aspects of the TBL. Rather, there is too much focus on the financial performance of institutions instead of on their broader economic value.

Globally, new rules and regulations are pushing more institutions to use the TBL. An instance is the 2024 United States Securities and Exchange Commission (SEC) regulations that would require

publicly traded institutions to report on their climate-related risks and greenhouse gas emissions. Similarly, in 2023, the European Union's Corporate Sustainability Reporting Directive requires approximately 50,000 companies to report annually on their business risks and opportunities related to social and environmental issues and the effects their operations have on people and the environment.

4.3.2 The Institutional theory

Institutional theory is relevant for studying the sustainability of DT strategies in South African TVET colleges as it helps evaluate how organisations are influenced by societal rules, norms, and structures. The theory emphasises how external pressures, such as regulations, cultural expectations, and industry standards, shape organisational behaviour. In the context of South African TVET colleges, Institutional theory helped assess how external pressures, for example, national education policies, governmental regulations, 4IR demands, and societal expectations, affect DT strategies. It assisted in explaining why some institutions are more successful in implementing sustainable strategies while others might struggle due to institutional constraints or external pressures, exploring how internal governance shapes DT adoption. South African institutions face tension between global competitiveness and localised socio-economic needs, necessitating adaptive business models (Mohamed Hashim et al., 2022a). The integration of green technologies and sustainable reporting mechanisms reflects efforts to align with global SDG agendas while addressing local resource constraints (Genga and Babalola, 2025).

Institutional theory helps evaluate how external pressures, for example, government regulations, industry standards, and societal expectations, shape the DT strategies of TVET colleges. A key aspect of Institutional theory is in assessing whether the DT aligns with the South African government's National Development Plan, DHET strategies, and other relevant educational policies, such as the National Digital and Future Skills Strategy (Tustin and van Aardt, 2022). Some theorists suggest that there is no policy document yet that provides guidance for Just Transition and green economic transformation across the different pillars of economic and social development (Freimann and Magnus 2023).

Freimann and Magnus (2023) claim that there is no policy that provides direct references on the greening of skills (apart from the inclusion of a few qualifications) and on education for sustainable development (policy gap). The National Skills Development Plan 2030 (NSDP) and the skills strategy under the Economic Reconstruction and Recovery Plan (ERRP) serve as key policy instruments guiding education and TVET colleges in South Africa. These strategic documents prioritise enhancing the labour-market relevance of TVET, broadening work-integrated learning opportunities,

and placing greater emphasis on the upskilling and reskilling of the workforce. Freimann and Magnus (2023) assert that national-level policies necessitate translation into actionable plans at the provincial level. Furthermore, integrating renewable energy, energy-efficiency infrastructure, and circular-economy initiatives with national and provincial skills development and inclusive employment promotion agendas.

As noted in South Africa's DT efforts, Institutional theory identifies systemic barriers like fragmented policy coordination and institutional resistance to change (Manda and Backhouse, 2018; BMR and GIZ, 2022). An instance of institutional resistance is the BMR and GIZ report, highlighting that only 53.57% of TVET colleges have a DT strategy, reflecting systemic inertia (Tustin and van Aardt, 2022). Another key aspect is evaluating how the DT is influenced by local cultural norms, socio-economic conditions, and the need for skills development in the local labour market. As noted by Freimann and Magnus (2023), that while national labour market information systems (LMIS) serve as a basis for anticipation mechanisms, assuming their existence and functionality, sectoral or locally focused skills forecasting offers more efficient alternatives. Fundamentally, they underscore that private-sector participation and a strong link between labour market projections and TVET systems are essential prerequisites for translating forecasting insights into the modernisation and greening of occupational standards and curricula.

Another key aspect is assessing how collaboration and competition with other institutions, such as universities, private institutions, and industry stakeholders, influence the sustainability of digital strategies. Poor intergovernmental coordination is a key hurdle, underscoring the need for Institutional theory to help analyse policy coherence (Manda and Backhouse, 2018). Using Institutional theory as a guiding framework, opportunities arise for the implementation of policy reforms designed to optimise DT agendas (Manda and Backhouse, 2018).

4.3.3 The Resource-Based theory

Resource-Based Theory (RBT) is highly relevant because it focuses on leveraging internal resources, such as ICT infrastructure and staff competencies, to achieve a competitive advantage. This theory is also known as the Resource-Based View (RBV); however, for the benefit of the study, the present study refers to it as RBT. The RBT argues that sustainable competitive advantage comes from unique institutional resources, tangible and intangible. Tangible resources may include infrastructure and IT systems, while intangible resources consist of digital literacy, knowledge management, and leadership (Kurilovas and Kubilinskiene, 2020). The BMR and GIZ reports identified insufficient funding and digital skills as critical barriers, aligning with RBT's emphasis on resource dependency (Tustin and van Aardt, 2022).

In the context of SDT, this would involve examining the resources that HEIs possess, such as digital infrastructure, human capital (faculty and staff with digital skills), financial resources, and intellectual property. In the context of DT, RBT concerns how an organisation's internal resources, such as technological capabilities, human capital, and organisational culture, enable or impede successful DT.

As noted that TVET systems frequently exhibit a temporal lag in adapting to shifts in labour market skill requirements (Freimann and Magnus, 2023). The low digital maturity and resistance to change require RBT-driven capacity-building (Modiba and Kekwaletswe, 2020; Tustin and van Aardt, 2022). The RBT helps assess TVET colleges' resource gaps, for example, budget constraints, outdated IT systems, and the role of strategic resource allocation in SDT (Modiba and Kekwaletswe, 2020). The theory highlights the importance of digital business engineering (DBE) to optimise ICT and human resources (Tustin and van Aardt, 2022; Hussein et al., 2024). Through Technological Resources, RBT evaluates the availability and management of technological infrastructure (hardware, software, and cloud resources) in the colleges to see whether these resources are sufficient for long-term sustainability (Chomunorwa et al., 2023).

The theory suggests that a sustainable competitive advantage is achievable through developing and leveraging unique and valuable resources that support SDT strategies. Limited government funding (12% of the education budget) strains infrastructure development and digital upskilling (Chomunorwa et al., 2023; Ndaba and Naidoo, 2024). The African Union has positioned human resource development as a paramount priority, acknowledging the pivotal role of TVET colleges in fostering sustainable development and social justice, aligning with the SDGs, the AU Agenda 2063, and its associated objectives (UNION et al., 2024). The commitment is operationalised through instruments such as the Continental TVET Strategy and the Science, Technology and Innovation Strategy for Africa (STISA), with the Continental TVET Strategy 2025-34 specifically targeting substantial and sustainable investment in human resource development.

The theory highlights the need for strategic resource allocation to sustain DT. Strategic resource allocation consists of investing in digital infrastructure, developing innovative online learning platforms, and fostering a culture of digital innovation. Application in South African HEIs consists of understanding how HEIs can strategically manage their resources to promote SDT, highlighting the importance of investing in digital capabilities and developing a resource-based view of SDT. In the context of sustainability, the RBT emphasises resource optimisation, for instance, partnerships for device access to advance SDG 12 (Responsible Consumption) and SDG 8 (Decent Work) (Holler et al., 2023; Ajani, 2024).

The sustainability of DT strategies in South African TVET colleges uses RBT as a lens to assess whether South African TVET colleges have the necessary resources, for example, digital infrastructure, skilled staff, financial investment, and to sustain their DT efforts, as well as exploring how effectively these resources are leveraged to maintain a competitive advantage in providing quality education. According to RBT, competitive advantage for South African TVET colleges lies in the value and rarity of education, placing these institutions in unique positions as rare commodities, making it easier to sustain and harder to imitate or substitute.

4.3.4 The Technology-Organisation-Environment framework

The Technology-Organisation-Environment (TOE) framework provides a structured lens to analyse DT challenges and opportunities in South African HEIs. The TOE framework evaluates and explains how technological, organisational, and environmental contexts influence technology adoption in institutions, shaping DT (Scholtz and Yakobi, 2023). The technology context of the TOE framework focuses on the compatibility of these technologies with the existing educational environment and their potential to support sustainable practices. Furthermore, this aspect examines the availability and characteristics of relevant technologies.

In the South African context, TOE includes the state of digital infrastructure, access to broadband internet, the prevalence of mobile devices, and the availability of learning management systems (LMS), Artificial Intelligence (AI) tools, and other digital resources. According to Tustin and van Aardt (2022), regarding the BMR and GIZ report, 45.89% of colleges lack full digital teaching or learning adoption due to poor ICT access. With only 22.9% of colleges being "digital challengers" with moderate ICT capacity. Assessing the technological readiness of TVET colleges involves evaluating the availability and functionality of digital infrastructure, platforms, tools, and resources for both teaching and administration.

Infrastructure challenges, including poor connectivity, outdated Information Technology (IT) systems and devices, and limited access to modern technologies, impede the adoption of DT. This is particularly evident in rural public universities and schools, where institutions often face additional obstacles such as unreliable electricity and insufficient bandwidth (Ajani, 2024; Chomunorwa et al., 2023). A recommendation by Scholtz and Yakobi (2023) is to invest in cloud-based solutions such as Amazon Web Services (AWS), a comprehensive, widely adopted cloud computing platform offered by Amazon.com, to reduce reliance on physical infrastructure. Implementing cloud-based technologies like AWS could enhance operational efficiency without substantial upfront costs, as they provide scalable infrastructure that reduces administrative burdens. Although public-private partnerships offer potential avenues for securing necessary funding for infrastructural improvements.

Collaborating with private entities assists in securing funding for upgrading educational facilities and leveraging their technological expertise.

The organisational context of the TOE framework considers the internal factors within HEIs, such as their organisational structure, culture, leadership, and resources. Analysing the internal capabilities of the TVET colleges includes the institution's capacity to adopt and implement digital technologies, the level of digital literacy among faculty and staff, and the presence of policies and strategies that support SDT strategies. Resistance to change among educators and underfunded institutions, such as "the missing middle," funding inequities limit progress (Ajani, 2022; Ndaba and Naidoo, 2024). Emphasis is placed on the organisation's ability to adapt to change and foster a culture of innovation and sustainability.

The environmental context of the TOE framework encompasses the external factors that influence HEIs, such as government policies, regulatory frameworks, economic conditions, and social expectations, specifically looking for supportive regulations and pressures (Abdurrahman et al., 2024). It also includes the broader societal context, such as the need to address the digital divide, promote inclusivity, and contribute to sustainable development goals (SDGs). The environmental context in South Africa also helps examine the specific challenges related to load shedding and limited resources (Chomunorwa et al., 2023). Socio-economic disparities, such as the digital divide and policy misalignment, such as underfunded ICT initiatives, exacerbate challenges (Ajani, 2022; Chomunorwa et al., 2023). Ajani (2024) argues that there is misalignment between national strategies and college-level implementation, resulting in policy fragmentation.

In applying SDT in HEIs, the TOE framework provides a holistic view of the factors that influence SDT adoption and implementation. The TOE framework can be used to guide the assessment process of SDT strategies in South African TVET colleges, assisting in analysing institutional readiness for DT. It highlights the need for holistic strategies, such as cloud-based infrastructure and public-private partnerships, to align DT with SDGs such as SDG 9 (Industry, Innovation) and SDG 4 (Quality Education) (Ajani, 2024). Identifying the key barriers and enablers of SDT in South African HEIs allows for the development of targeted strategies and interventions.

Abdurrahman, Gustomo and Prasetio (2024) note that the TOE framework identifies three key aspects that influence technology adoption in firms: the technological context, organisational context and environmental context. The present study on DT in TVET colleges is guided by this framework to analyse factors like the availability of digital infrastructure (technology), institutional capacity (organisation), and the influence of government policies, socio-economic factors, and regulations (environment) (Nkambule and Ngubane, 2023; Sibiya, 2024).

4.3.5 The Theory for Design and Action

Theory for Design and Action (TDA) focuses on designing sustainable interventions, providing a framework for designing actionable interventions through iterative problem-solving. The theory is relevant to the present study as it emphasises the design and action aspects of technological innovations, focusing on creating frameworks for understanding and guiding interventions in real-world settings (Hoadley and Campos, 2022). The present study is especially valuable as it aims to provide actionable insights for real-world applications. The goal of the study was to formulate practical DT strategies that are sustainable over time. The theory guided the present study by offering a structured approach to not only understanding the challenges and opportunities of DT in TVET colleges but also developing frameworks and guidelines for effective implementation and improvement. TOE guides the development of phased implementation plans, for example, prioritising cybersecurity, HR capacity-building (Tustin and van Aardt, 2022; Hussein et al., 2024).

Through Evaluative Design, TDA assesses how effectively the DT strategies are designed to achieve long-term goals. Evaluating whether the DT strategies are scalable and adaptable to future changes in technology, society, and education. The TDA supports participatory approaches, such as involving staff and students as "partners in change" to foster a buy-in (BMR and GIZ, 2022). Furthermore, it provides actionable recommendations for continuous improvement in DT strategies, ensuring their alignment with sustainability goals and addressing barriers as they arise. The BMR and GIZ (2022) report recommends using DXRI scores to iteratively measure progress, reflecting TDA's emphasis on adaptive, evidence-based design (Tustin and van Aardt, 2022; Hussein et al., 2024). TDA has the potential to transform actionable insights into actionable strategies for TVET colleges to implement SDT plans. TDA is used as an adaptive roadmap to design phased strategies, prioritising cybersecurity and HR capacity-building (BMR and GIZ, 2022).

Triangulating theories, the present study aimed to provide a comprehensive analysis of the factors that influence the sustainability of DT strategies in TVET colleges. Triangulating the TOE framework with RBT enables an understanding of both internal resources and external factors that affect digital adoption. Institutional Theory contextualises policy challenges. The TBL theory then assesses the sustainability of the strategies from an economic, social, and environmental perspective, ensuring a holistic measurement of impact. Finally, insights gained are then transformed into actionable strategies for TVET colleges to implement SDT plans. Additionally, TDA theory enables the design of adaptive strategies. It ensures that DT initiatives are adaptive, scalable, and aligned with long-term sustainability goals across economic, social, and environmental dimensions.

Researchers suggest the use of empirical validation using mixed methods, for example, DXRI benchmarking, stakeholder interviews, to operationalise this framework (BMR and GIZ, 2022; Tustin and van Aardt, 2022; Hussein et al., 2024). Continuous evaluation is vital for guaranteeing the sustainability of DT, and this is achievable by monitoring KPIs related to student success (performance, retention, graduation), staff feedback on digital initiatives, and technology performance (uptime, user satisfaction, academic effectiveness) (Kurilovas and Kubilinskiene, 2020).

4.3.6 Systems theory

Digital transformation is perceived as both a system (encompassing structural components) and a systematic process (involving sequential implementation). This dualistic nature underscores the idea that DT requires not only technological implementation but also a deep comprehension of how these technologies affect organisational processes. Systems theory highlights interdependencies between technological adoption, curriculum redesign, and institutional governance. South African studies reveal that fragmented infrastructure and unequal access to 4IR tools create systemic barriers (Mabidi, 2024). A holistic systems approach is critical for integrating sustainability into curricula, campus operations, and community engagement (Genga and Babalola, 2025). In concurrence, Freimann and Magnus (2023) posit that addressing the limitations of current TVET systems requires broad-based reforms, requiring careful coordination with related policy frameworks. Such reforms should incorporate the alignment of TVET with sustainability and digitalisation policies, the implementation of multilevel governance strategies, and close interlinkage with other forms of education.

4.3.7 Innovation Diffusion theory

According to Rogers (2003), the Diffusion of Innovations Theory focuses on how innovations spread within social systems, including the role of communication channels, social norms, and adopter categories. Within the South African context, the theory may explain how digital technologies diffuse through TVET colleges, influenced by cultural readiness and change agents managing resistance. The adoption of digital technologies aligns with principles of innovation diffusion, where scalability and stakeholder buy-in determine success. Bibliometric analyses show that SDT in developing countries prioritises technologies like AI and blockchain to bridge educational gaps while promoting environmental sustainability (Omar and Abdullahi, 2024). However, resistance to change and skill shortages in South Africa slow the uptake of innovations like MOOCs and virtual labs (Mabidi, 2024). Debating the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) discussion paper ‘Skills for a Just Transition to a Green Future’ (2022), Freimann and Magnus (2023) posit that current TVET systems are ill-equipped to support a Just Transition. Highlighting the systemic weaknesses within these systems, including deficiencies in governance structures and suboptimal financial

allocations. There is a lack of adequately trained educators and a disconnect from other educational pathways, which collectively reinforce the perception of TVET as a second-rate educational option.

4.3.8 Organisational Change theory

Institutional sustainability requires cultural shifts toward DEI. Research on African higher education underscores the need for digital leadership to drive policy reforms, address mental health challenges, and reduce the digital divide (Genga and Babalola, 2025). Strategies include fostering collaborative governance and redefining institutional missions to embed DEI in digital initiatives.

4.3.9 Representation theory

The theory of Representation as introduced by Lauterbach, Mueller, Kahrau, and Maedche (2020) focuses on the concept of representational complexity in digitalising work within organisations. It highlights two main dependencies, namely, System and Semantic Dependency. System Dependency refers to the extent to which a task is supported by a digital system. Semantic dependency refers to the degree of semantic understanding required for task completion. The interplay between these dependencies creates representational complexity, which can constrain effective use of digital systems and explain variations in learning effort and adoption rates among users. The theory is grounded in a case study of a European bank but is conceptualised for broader organisational contexts, emphasising that effective digitalisation is not just a technical issue but also a matter of how tasks and systems are represented and understood by users (Lauterbach et al., 2020). The underlying principles from a banking context are applicable to higher education, especially in environments undergoing rapid digital change and facing resource constraints.

Recent studies on SDT in South African HEIs focus on understanding opportunities, threats, and the practical implications of digital adoption for long-term sustainability (Newlin and Legg Jack, 2025). The studies emphasise the need for transformative changes in pedagogy, technology, and institutional strategies. Furthermore, employing qualitative methods such as content analysis and participant interviews, to explore how digital strategies align with sustainability goals, for example, the UN SDGs, address challenges unique to disadvantaged HEIs.

The challenges identified by Lauterbach et al. (2020) such as the co-dependency between system and task, are adaptable to HEIs, where DT often requires new ways of teaching, learning, and administration. Understanding representational complexity assists in explaining why some digital initiatives succeed or fail, especially when users must adapt to new systems and semantic frameworks (Lauterbach et al., 2020; Newlin and Legg Jack, 2025).

Tasks such as teaching, assessment, and administration are deeply intertwined with both technological systems and the meanings attached to educational practices in HEIs. Representation theory provides a lens to analyse how these dependencies impact the effective use of digital tools in universities (Lauterbach et al., 2020; Newlin and Legg Jack, 2025). Furthermore, representation theory offers a structured way to interpret qualitative findings about user experiences, barriers, and learning curves in DT efforts, which supports the identification of specific points where representational complexity may impede or facilitate sustainable DT.

4.4 Practical metrics and tools for sustainability evaluation

Various models are designed to guide institutions through their DT process, for instance, the DXRI and the Staged roadmap model. There is scant literature on quantitative measurement scales of information systems in South Africa's TVET colleges (Mphahlele, Kekwaletswe and Seaba, 2024).

4.4.1 Digital Transformation Readiness Index (DXRI)

A 100-point scale is used to quantify readiness across five stages (inputs, activities, outputs, outcomes, impact). The BMR and GIZ report highlights an overall DXRI score of 54.61 (mediocre), indicating insufficient conditions for sustainable implementation (Tustin and van Aardt, 2022). Together with Maturity Levels, 47.1% were classified as "digital dabblers" (limited ICT capacity), and only 4.6% were "digital trailblazers" (Tustin and van Aardt, 2022).

To foster sustainable and effective DT, South African TVET colleges should routinely assess their readiness and benchmark progress across institutions. This assessment may be conducted using the DXRI as a framework for continuous evaluation and comparative analysis between colleges. Emphasis should be placed on integrating green technologies, such as cloud-based solutions and energy-efficient hardware, to enhance resource efficiency and reduce environmental impact (Mohamed Hashim et al., 2022a). Additionally, Institutional theory-informed policy reforms should be implemented to align college strategies with DHET directives and global SDG frameworks.

4.4.2 Staged roadmap model

This model is often referred to as the Stage-Gate Model or Phase-Gate Process; however, for the benefit of the study, the present study used the Staged roadmap model. It is a strategic project management approach used primarily in product development. The framework breaks down the DT process into clear, sequential stages. Each stage has defined objectives, milestones, and timelines, ensuring a structured approach to implementation (EPAM Solutions, 2024). The widely used model organises the transformation into clear, sequential stages, where each stage builds upon the previous

accomplishments. Well-defined objectives and timelines for each stage ensure a methodical advancement toward the goal (EPAM Solutions, 2024).

4.4.3 Business Architecture Framework

The Business Architecture framework uses the organisation's architecture and capabilities to ensure digital solutions match process needs and enable valuable innovation (EPAM Solutions, 2024). The primary purpose of this DT framework is to connect strategy with execution, providing a common language that helps stakeholders understand relationships between different business elements. It aligns DT initiatives with broader business goals. It ensures that digital solutions match process needs and enable innovation, providing a common language for stakeholders (EPAM Solutions, 2024). The frameworks assist organisations in aligning DT initiatives with larger business goals.

4.4.4 Agile Digital Transformation Framework

The Agile digital transformation strategy framework promotes flexibility and adaptability, allowing organisations to respond quickly to changes and create a culture of continuous improvement. It emphasises iterative processes and rapid adjustments to strategies based on market dynamics (EPAM Solutions, 2024). The Agile framework enables an institution to assess its current state and make rapid adjustments to adapt to new business models.

The preceding theories collectively emphasise the need for context-sensitive, interdisciplinary frameworks to balance technological advancement with equitable and sustainable outcomes, applicable in South Africa's higher education landscape. These theories are complementary and, together, provide a holistic understanding of assessing and evaluating the sustainability of DT strategies in South African TVET colleges, with a focus on both theoretical analysis and practical applications for long-term success.

The next section provides the conceptual research framework that guided the present study.

4.5 Conceptual research framework for Sustainability Evaluation of Digital Strategies in TVET colleges

Elia et al. (2024) posit that a DT strategy comprises a purpose for the initiative, as well as strategic directions for DT. The sustainability of DT strategies in South African TVET colleges can be evaluated through a qualitative approach framework that integrates theoretical models and practical metrics, addressing socio-economic, environmental, and institutional dimensions. Only 9.3% of the 50 public TVET colleges spread across 294 registered campuses nationwide have implemented DT plans (BMR and GIZ, 2022). The significant gaps reported include: digital workplace tools (73%

colleges are deficient), cybersecurity measures and industry-aligned curriculum updates. The current strategy study aims to first understand current capabilities and then develop executable plans to bridge the identified gaps. The 2022 readiness study provides essential baseline data, while a subsequent strategy study would operationalise its recommendations through measurable interventions (BMR and GIZ, 2022).

A conceptualised DT research framework is critical as it provides a structured blueprint for the strategic integration of emerging technologies into all facets of institutional operations. The framework enables the institution to adapt to the evolving educational landscape, enhance student engagement and learning outcomes, optimise administrative processes, and maintain relevance in a technologically driven environment (EPAM Solutions, 2024). Through offering a systematic approach to DT, the conceptual research framework empowers the institution to achieve its digital objectives in a coherent and effective manner, thereby enhancing its contribution to national skills development and economic growth. With as much as 48% of digital initiatives by businesses reported, a leading research and advisory company, achieving their business outcomes successfully indicates significant challenges in implementation and execution. Thus, South African TVET colleges must establish a digital strategy based on key principles to go through the DT process successfully.

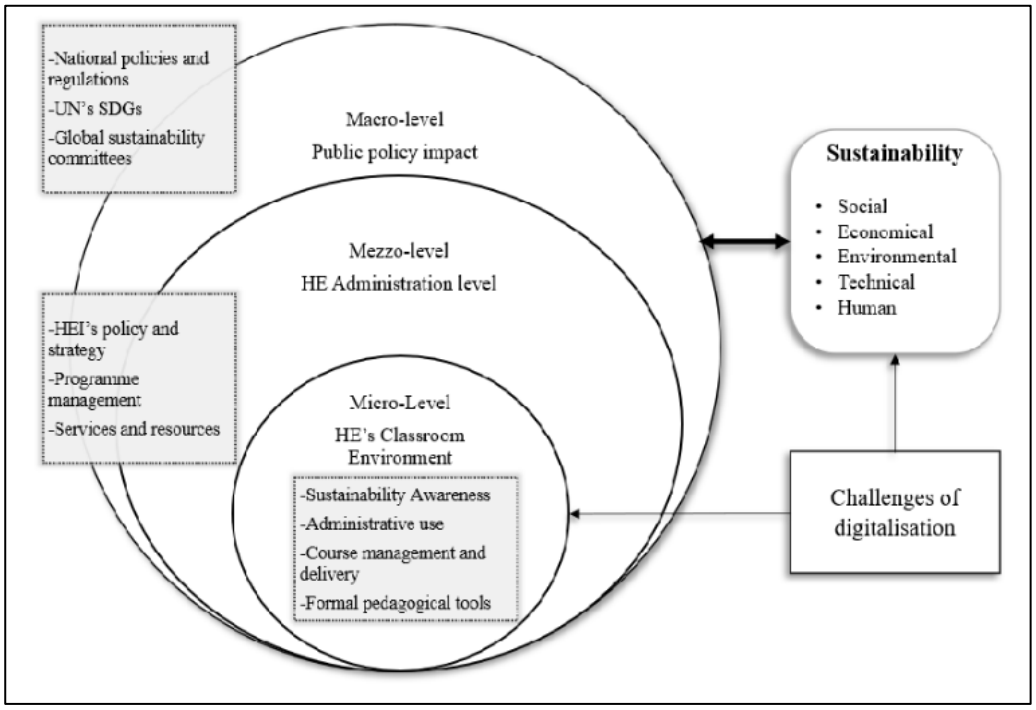


Figure 4.2 A conceptual research framework for SDT in higher education institutions (Hamadi and El-Den, 2024)

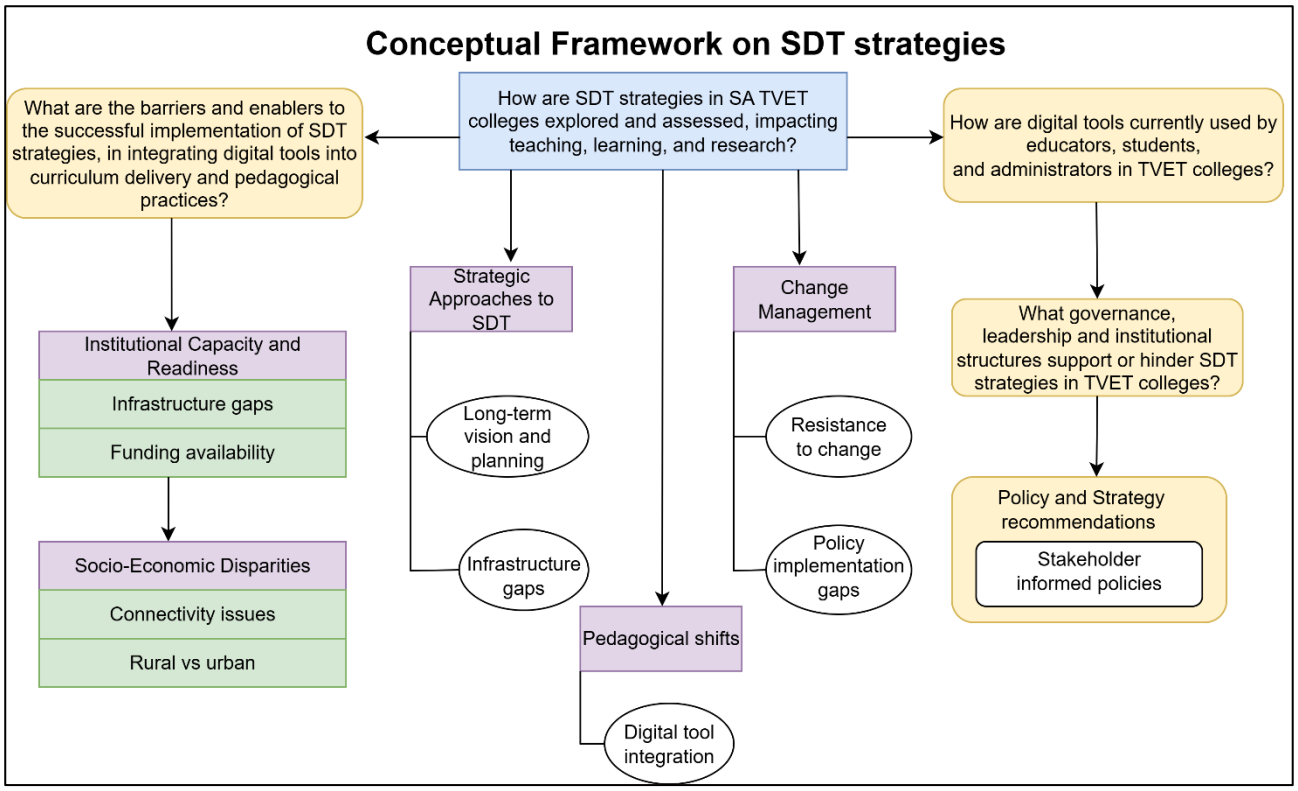


Figure 4.3: A visual Conceptual Research Framework for evaluating SDT in South African TVET colleges

Despite existing research on DT in education, there is a lack of a widely adopted framework specifically for South African TVET colleges (Nkalane, 2018; Sibiya, 2024). Furthermore, research in South Africa often overlooks the environmental dimension of sustainability, focusing primarily on socio-economic factors (Nkambule and Ngubane, 2023; Sibiya, 2024). There is also limited research on DT strategies tailored to South African TVET colleges and, therefore, a need for greater awareness of SDT and its future impact (Geressu, 2014; Alenezi and Akour, 2023). The present study implies that SDT strategies should adopt a holistic approach, integrating economic, social, and environmental dimensions. Socioeconomic factors include inclusivity, training and development, skills gap reduction, technology adoption, digital resources, infrastructure development, and clear strategic goals. Environmental factors include mitigating the impact of load shedding, implementing sustainable energy production, and reducing waste (Nkambule and Ngubane, 2023; Sibiya, 2024).

4.6 Implemented Initiatives and Strategies

The implementation of transformative initiatives within the South African context presents both challenges and opportunities shaped by historical and socio-economic factors. Challenges such as resistance to change, inadequate infrastructure, and disparities in funding are deeply rooted in historical inequalities, posing significant barriers to sustainable progress (Mabidi, 2024; Genga and

Babalola, 2025). Conversely, opportunities exist in the form of curriculum redesign, technology-driven social inclusion, and collaborative partnerships for resource sharing, which enhances accessibility and equity in various sectors (Mabidi, 2024; Omar and Abdullahi, 2024). As Freimann and Magnus (2023) argue, the employment gains of a skilled workforce with green skills will not materialise if the private sector is not comprehensively incentivised and supported to develop Green Jobs and demand Green Skills. Moreover, Freimann and Magnus (2023) argue that there is a lack of motivation for institutions to invest in substantial environmental protection measures when regulatory enforcement by authorities is perceived as inadequate, and a lack of immediate financial returns in the form of reduced expenditure or increased income.

There have been various initiatives and strategies to develop and evaluate SDT within South African TVET colleges. These initiatives reflect a concerted effort by South African HEIs to embrace DT sustainably, focusing on infrastructure development, digital literacy, innovative teaching methodologies, and inclusivity to enhance the overall educational experience.

4.6.1 Skills for Green Jobs (S4GJ) programme

The Skills for Green Jobs (S4GJ) programme, a South African-German initiative, aims to promote a green economy by developing labour-market-oriented green skills, advancing green technologies, and raising awareness, particularly within small and medium-sized enterprises (SMEs) and TVET colleges. The collaborative initiative includes the South African Departments of Science and Technology (DST) and Higher Education and Training (DHET), in partnership with the Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ). The S4GJ is a targeted programme focusing on green job readiness. It actively integrates industry-relevant green skills into specific vocational programmes. Additionally, it actively prepares students for the emerging green job market across eleven TVET colleges in five of South Africa's nine provinces, namely Gauteng, Mpumalanga, the Eastern, Western, and Northern Cape.

4.6.2 Greening of Colleges Initiative

The DHET has previously launched an initiative geared towards incorporating sustainability into TVET colleges (Singh and Feuerriegel, 2013). The initiative was initially piloted in select colleges under S4GJ, and later scaled to all public TVET colleges (Freimann and Magnus, 2023). Drawing on international best practices for the ecological transformation of tertiary institutions, the 'Greening of Colleges' initiative was introduced in early May 2013 with the aim of cultivating environmentally responsible campuses within the TVET sector (BMR and GIZ, 2022). The initial pilot implementation of the initiative encompassed seven colleges, namely Boland TVET College, Central Johannesburg

TVET College, Eastcape Midlands TVET College, Northlink TVET College, Northern Cape Rural TVET College, Port Elizabeth TVET College, and Umfolozi TVET College.

The “Greening of Colleges” initiative is a holistic approach to transform training providers with a focus on five strategic dimensions of greening: Green Campus, Green Curriculum, Green Community, Green Research, and Green Culture. The national initiative actively seeks to integrate sustainability principles into the TVET sector through several key mechanisms. These include the development of training curricula focused on renewable energy and energy efficiency, the integration of optional vocational subjects pertaining to green technologies, and the implementation of awareness campaigns to promote sustainable development principles. The 2013 Renewable Energy Technology subject was introduced within the National Certificate Vocational (NCV) electrical curriculum. The program has expanded from 5 to 19 TVET colleges (Freimann and Magnus, 2023).

The S4GJ programme and the Greening of Colleges Initiative are complementary but distinct components of South Africa’s efforts to align technical and vocational education with sustainability goals. The S4GJ programme is more specialised, equipping students with industry-aligned skills for green jobs, while the Greening of Colleges initiative is broader as it also entails embedding sustainability principles across multiple dimensions of TVET institutions. Both initiatives complement each other in advancing sustainability within South African TVET colleges.

4.6.3 African Continental TVET Strategy 2025-34 for Sustainable Development

The African Union has revised its 2015 Continental TVET Strategy to align with the evolving trends and priorities in continental and global skills development (UNION et al., 2024). The revised "African Continental TVET Strategy 2025-34 for Sustainable Development" is a Pan-African Initiative that provides a framework for national TVET policies to enhance youth employment and economic growth. While not exclusive to South Africa, this strategy offers guidance for South African TVET colleges to align with and integrate sustainability into their DT efforts. The framework emphasises the need for TVET systems to adapt to sustainable development goals (UNION et al., 2024).

Considering the four predominant trends: digitisation, climate change, demographic shifts, and migration. The framework suggests that the next TVET strategy be closely aligned with the targets of the AU Agenda 2063, the 2030 Agenda for Sustainable Development, and other pivotal regional and global agendas. The development of a strategic planning framework for national implementation involved a pilot phase in The Gambia, Liberia, and Mali during 2022 (Grech, 2023). The framework was subsequently refined through an iterative process incorporating feedback from the pilot countries, additional research, and critical reflection, with the development and refinement facilitated by the

Pan African Network for the Acceleration of Digital Transformation of TVET and Skills Development Systems in Africa. Other critical areas emphasised include enhancing the calibre of the teaching workforce and the image of the TVET sector.

While multiple initiatives address aspects of DT and sustainability within South African TVET colleges, there is no singular, comprehensive national plan that fully integrates both elements across all institutions. Continued efforts are necessary to develop a unified strategy that ensures SDT in the TVET sector.

4.7 Chapter summary

Chapter Four provided the theoretical foundation and underpinning theories for the present study. The conceptual research framework, which focuses on evaluating SDT strategies within TVET institutions, was then provided. The discussion began by acknowledging the limitations of commonly used theoretical frameworks, including Organisational Change Theory and Diffusion of Innovations Theory, in capturing the multidimensional and systemic nature of SDT within the higher education sector.

An in-depth examination of the SIS theoretical framework revealed its appropriateness for the present study. The SIS framework extends beyond a checklist of sustainability objectives; it encourages institutions to conceptualise their information systems as drivers of transformative change. The conceptual research framework embeds ecological responsibility, social justice, and long-term knowledge development into digital initiatives. The SIS framework supports South African HEIs in creating more inclusive learning environments, environmentally conscious campuses, and resilient institutional futures.

Importantly, the SIS framework offers a holistic and action-oriented model that aligns well with the qualitative nature of the present study. Incorporating sustainability principles into the evaluation process, the SIS framework and the conceptual research framework enables the present study to evaluate sustainable DT strategies in a manner that is both systemic and contextually relevant. Moreover, the framework assists in bridging the gap between policy and practice, supporting national development priorities, and promoting the advancement of equitable, future-ready education systems.

In this regard, SIS framework is not merely a theoretical lens but also a strategic tool for guiding effective and inclusive DT in the context of both the South African TVET and broader HEI sectors.

The next chapter, Chapter Five, describes the research methodology followed in conducting the present study, detailing the research philosophy, research approach, research strategy, data collection methods, and analytical procedures employed.

Chapter Five: Research Methodology

5.1 Introduction

The preceding Chapter Four discussed the theoretical underpinnings of the present study and provided the conceptual research framework. Chapter Five describes and justifies the research methods used in the present study. The chapter presents the steps undertaken to collect and analyse data from a sample of seven TVET college campuses in South Africa, with the intention of satisfying the objectives of the present study. The chapter discusses the paradigm, research approach, research design, data gathering, sampling, data analysis methods, and ethical considerations.

This research methodology chapter begins with Section 5.1, setting the stage for the chapter. Section 5.2 Research Design considers the overarching plan and strategy for the study. Section 5.3 Research Paradigm introduces the fundamental beliefs regarding the nature of reality and knowledge (deals with the research philosophy and paradigm, delving into philosophical underpinnings), and Section 5.4 Ontological and Epistemological Perspectives describes the specific views on the nature of being (ontology) and how knowledge is acquired (epistemology) within the chosen paradigm. Section 5.5, Research Approach, discusses the qualitative inquiry undertaken, which is directly influenced by the paradigm. Section 5.6 outlines the specific strategies and procedures used to achieve the research objectives, including practical steps. Section 5.7 Role of the Researcher follows, discussing reflexivity, potential biases, and how the researcher's positionality may influence the study. In Section 5.8 Research Instruments, the tools and methods used to gather data are detailed. Section 5.9, Data Management, explains how the raw data were organised, stored, and prepared for analysis. Section 5.10 Analysis of data discusses the systematic process of making sense of the collected data. For Section 5.11 Measures of Trustworthiness, it is essential to demonstrate the rigour and credibility of primarily qualitative research. Section 5.12 examines the ethical considerations of the research, how it adheres to ethical guidelines, and how it protects participants. The chapter concludes with Section 5.13, Chapter summary, which summarises the chapter and transitions to the next chapter.

5.2 Research design

Addressing the multifaceted nature of reliability in qualitative research necessitates a departure from the quantitative emphasis on exact replicability, acknowledging the diverse paradigms inherent in qualitative inquiry. Given this complexity, reliability in qualitative research is more appropriately conceptualised as consistency, where a degree of variability in results is acceptable as long as the methodology and epistemological approach consistently yield ontologically similar data. This degree

of variability in study findings then allows for variations in richness and ambience within comparable dimensions (Dhobi, 2023). To uphold the reliability of the present study, meticulous attention was given to maintaining consistency throughout the research process. This involved ensuring that participants were exposed to uniform questions and afforded equitable opportunities to articulate their perspectives comprehensively (Ahmed, 2024).

In qualitative research, the focus is on the quality of information obtained through various methods such as interviews, focus group discussions, case studies, narrative analysis, introspection, and interaction with respondents (Dhobi, 2023). Unlike quantitative research, where reliability refers to exact replicability, qualitative research acknowledges the role of the researcher in the construction of knowledge. Qualitative research recognises the subjective experiences and interpretations of individuals (Dhobi, 2023). In qualitative studies, researchers often aim to understand and describe the world of human experience (Golafshani, 2015). Ensuring trustworthiness is paramount in qualitative research to establish the credibility and reliability of findings, especially considering their subjective nature (Ahmed, 2024). Qualitative researchers implement various strategies to enhance the credibility of their research, considering that reliability and validity are fundamental for ensuring the soundness of research and the integrity of its conclusions (Noble and Smith, 2025).

Qualitative research operates on foundational assumptions encompassing ontology, epistemology, and axiology (Dhobi, 2023). Ontology delves into the nature of reality, exploring whether it is singular and objective or multiple and subjective (Dhobi, 2023). Epistemology concerns itself with the nature of knowledge, examining how knowledge is acquired and validated (Dhobi, 2023). Axiology investigates the role of values in the process of knowledge production, recognising that research is not value-neutral and that researchers' values can influence their interpretations and findings (Dhobi, 2023). The philosophical underpinnings of qualitative research include positivism, interpretivism, constructivism, and critical theory. These underpinnings significantly shape the research design and influence the types of research questions asked, the approaches taken, and the data collection and analysis methods employed (Dhobi, 2023). The essence of qualitative research lies in deciphering and identifying patterns within textual data to construct a meaningful representation while preserving its depth and multifaceted nature (Leung, 2015).

The application and appropriateness of research methods are essential for ensuring the credibility of qualitative research findings (Noble and Smith, 2025). Qualitative researchers adopt strategies to ensure the trustworthiness of their findings, whereas quantitative researchers use statistical methods to establish validity and reliability (Noble and Smith, 2025). Strategies such as prolonged engagement, triangulation, member checking, peer debriefing, thick description, and reflexivity are

used to ensure that the findings are credible and accurately reflect participants' experiences and perspectives (Joseph et al., 2024). Trustworthiness in qualitative research encompasses various dimensions, including credibility, transferability, dependability, and confirmability, which collectively assess the trustworthiness of the research findings (Korstjens and Moser, 2018; Ahmed, 2024). The credibility of research hinges on the plausibility and trustworthiness of the findings, with alignment between theory, research questions, data collection, analysis, and results (Stenfors, Kajamaa and Bennett, 2020).

The transparency and critical evaluation by the scholarly community can be encouraged through the methodical application of measures to ensure trustworthiness, enhancing the precision and reliability of qualitative research. Researchers' philosophical inclinations or paradigm preferences determine the research process and influence the understanding of research findings (Ataro, 2020). Furthermore, the researcher's values, assumptions, and biases inevitably shape the research process, from problem formulation to data interpretation.

An interpretive multiple-case study design was employed to explore the organisational, cultural, and social dynamics underpinning SDT efforts in public TVET colleges. This design supports a context-sensitive analysis and is appropriate for capturing nuanced, multi-stakeholder perspectives within real-world educational environments (Mtshali, Maistry and Govender, 2020). Furthermore, this design enables the emergence of rich, descriptive accounts that illuminate complex interactions and reveal unanticipated phenomena such as infrastructure challenges, digital literacy gaps, or innovative leadership practices (Ramorola, 2018; Türk, 2023). A multiple-case study approach was used to provide a thorough examination of the intricacies of technology integration and DT in the workplace (Mtshali et al., 2020). It assisted in identifying significant elements that affect the success of organisational learning and adaptation. The case study methodology, which combined interviews and document analysis, provided a thorough understanding of the difficulties developing nations face in implementing DT initiatives. The use of multiple cases enabled cross-case comparisons, identifying patterns, and developing a more robust understanding of the factors influencing SDT success.

This overarching design provides the framework within which the philosophical stance (Section 5.3) and specific methodological procedures (Section 5.6) are operationalised.

5.3 Research philosophy and paradigm

In the realm of research, a paradigm serves as a comprehensive framework of shared assumptions, values, and practices that guide the investigation, interpretation, and application of knowledge within a specific discipline or field (Pretorius, 2024; William, 2024). It embodies a researcher's fundamental

beliefs about the nature of reality (ontology), the nature of knowledge (epistemology), and the role of values in the research process (axiology) (Rashid, Rashid, Warraich, Sabir and Waseem, 2019). Research paradigms serve as the bedrock upon which coherent and philosophically sound research designs are constructed, particularly in the social sciences and humanities (Pretorius, 2024). Similarly, Neuman (2014) explains that social science research is integral within a "reality-based community". This is interpreted to mean that such research relies on people carefully studying experiences, events, and facts within a social reality.

Research paradigms are distinguished by their unique approaches to ontology, epistemology, and axiology, offering varied lenses through which to examine and comprehend the complexities of the human experience (Pretorius, 2024). Selecting a research paradigm is a key decision influencing the entire research process, from the formulation of research questions to the selection of methodologies and the interpretation of findings (Pretorius, 2024). Paradigms are conceptual lenses through which researchers examine the methodological aspects of their research projects in order to determine the research methods that should be used and how collected data should be analysed (Kivunja and Kuyini, 2017; Williams, 2021).

According to Adil, Khan and Ahmad (2025), the selected paradigm determines the acceptable types of questions, the methods used to gather and analyse data, and the criteria for evaluating the validity and reliability of findings. Furthermore, Adil et al. (2025) assert that the chosen paradigm determines a researcher's role in the research project. The process of selecting a paradigm requires a deep understanding of its philosophical underpinnings and its implications for research practice. Researchers must justify their choices by demonstrating how their chosen paradigm aligns with the research questions, the nature of the phenomenon under investigation, and the researcher's own values and beliefs (Buriro, Ednut and Khatoon, 2021). Kivunja and Kuyini (2017) reinforce this view, stating that a paradigm consists of the beliefs and principles that shape how a researcher perceives the world and the manner in which the researcher interprets and acts within it. It is thus recommended that researchers consider whether a particular design choice is suitable and aligns with their own worldviews, skills, and personalities. In carefully considering these factors, the present study ensured that it was both rigorous and meaningful, contributing to a deeper understanding of the world around it.

5.3.1 The Positivism

The positivist methodology typically involves quantitative data collection methods, such as experiments and surveys, and statistical analysis techniques to identify patterns and relationships between variables (Park, Konge and Artino, 2020). Positivism is aligned with the hypothetico-

deductive model of science that builds on verifying a priori hypotheses and experimentation by operationalising variables and measures. The results from hypothesis testing are used to inform and advance science (Park et al., 2020). Studies aligned with positivism generally focus on identifying explanatory associations or causal relationships through quantitative approaches, where empirically based results from large sample sizes are favoured. In this regard, generalisable inferences, replication of results, and controlled experimentation have been principles guiding positivist science (Park et al., 2020). Positivism aims to demonstrate that phenomena in the field of social sciences and humanities are equally subject to measurement as natural phenomena (Park et al., 2020).

In contrast, the constructivist-interpretivist paradigm, with its focus on understanding human experiences, meanings, and perspectives, is more appropriate for research questions that explore complex social phenomena, cultural contexts, and individual interpretations (Dhobi, 2023; Adil et al., 2025).

5.3.2 The Constructivist-interpretive paradigm

The constructivist-interpretivist paradigm assumes that reality is socially constructed and that knowledge is created through interaction and interpretation. The constructivist perspective views data and observations as products of individual inputs and interpretations (Tanlaka and Aryal, 2025). This paradigm emphasises qualitative data collection methods, such as interviews, focus groups, and ethnographic studies, to gather rich descriptive data that captures the nuances of human experience. A constructivist researcher typically employs a variety of qualitative data analysis techniques, such as thematic analysis and discourse analysis, to identify patterns, themes, and meanings within the data. According to Belharar, Laamrani and Chakor (2023), constructivism assumes that reality is constructed by individuals through their social interaction. Moreover, Tanlaka and Aryal (2025) state that it is a theory of knowledge that posits that humans construct meaning from their experiences.

The paradigm emphasises the importance of context and the researcher's active role in the research process. Interpretivism believes that reality is not objectively determined, but rather socially constructed.

The interpretivist paradigm enables researchers to explore an in-depth understanding of the phenomena. Interpretivism is related to the uniqueness of a specific circumstance that contributes to the profound pursuit of contextual depth (Dhobi, 2023). Interpretivism concentrates on meaning and interprets knowledge and lived experiences. Interpretivism is sometimes known as anti-positivism (Dhobi, 2023). Interpretivism uses qualitative research to focus on descriptions of a phenomenon.

Given that the present study focuses on understanding the lived experiences and perspectives of individuals within a specific social context, the constructivist-interpretivist paradigm aligns well with the qualitative design and data collection methods employed (William, 2024). The interpretivist perspective focuses on the importance of understanding human behaviour, interactions, and society (Dhobi, 2023). Interpretivism is a philosophical stance that emphasises the importance of interpreting the meanings and perspectives of the people being studied (Tanlaka and Aryal, 2025). Belharar et al. (2023) contend that constructivism argues that knowledge is contextual and situated, and events shape each other in multi-directional ways. Qualitative research helps to explore new phenomena and to capture individual experiences.

The data collection methods, such as interviews and document analysis, are consistent with the constructivist-interpretivist paradigm (Pretorius, 2024). These data collection methods allow for the exploration of individual perspectives and the construction of meaning within a specific context. The interpretive paradigm is well-suited for qualitative research methods, as it acknowledges the subjective nature of human experience and the importance of understanding the context in which that experience occurs (William, 2024).

The present study used a qualitative approach for data collection, including interviews and document analysis. As the constructivist-interpretivist paradigm prioritises understanding human experiences and the meanings individuals ascribe to their world, it guided this present study (Golafshani, 2015; William, 2024). This paradigm aligns well with the qualitative methodology, as both emphasise exploring and interpreting human behaviour and in-depth lived experiences.

5.3.3 Comparative analysis of the paradigms

Positivism, a dominant paradigm in the natural sciences and social sciences for much of the 20th century, posits that reality is objective, measurable, and independent of the observer (Park et al., 2020; Dhobi, 2023). This paradigm adopts a realist ontological stance, assuming that the world exists as an objective reality that can be discovered and understood through scientific investigation (William, 2024). Positivist epistemology emphasises objectivity, neutrality, and the use of quantitative methods to establish universal laws and causal relationships. Positivists strive for value-free research, believing that researchers should remain detached from the subject of inquiry to avoid bias (Pretorius, 2024). The constructivist-interpretivist paradigm offers a contrasting perspective, emphasising the subjective nature of reality and the importance of understanding human experiences within their specific contexts.

Conversely to positivism's objective stance, constructivist-interpretivism asserts that reality is socially constructed through individual and collective interpretations (Tanlaka and Aryal, 2025). The

paradigm adopts a relativist ontological stance, acknowledging that multiple realities exist and that these realities are shaped by social, cultural, and historical factors (Dhobi, 2023). Constructivist-interpretivist epistemology emphasises the importance of understanding the meanings that individuals ascribe to their experiences and the role of the researcher in co-constructing knowledge. Interpretivism fosters the value of qualitative data in search of knowledge (Dhobi, 2023). Interpretivist researchers embrace subjectivity, recognising that their own values and perspectives inevitably influence the research process (Tanlaka and Aryal, 2025). The healthy interaction between them can be significant in drawing contextualised experiences of the participant (Dhobi, 2023).

Choosing between positivism and constructivist-interpretivism depends on the research question and the nature of the phenomenon under investigation (Darby, Fugate and Murray, 2019; William, 2024). For research questions that seek to establish causal relationships or measure objective phenomena, positivism may be the more appropriate paradigm. However, for research questions that aim to understand complex social phenomena or explore individual experiences, constructivist-interpretivism offers a more suitable framework. This approach acknowledges the active role of the researcher in shaping the research process and recognises the importance of understanding the context in which data is collected and analysed (Darby et al., 2019).

To justify the selection of a research paradigm, it is essential to conduct a comparative analysis of different paradigms, highlighting their strengths and weaknesses in relation to the research question and the nature of the phenomenon under investigation (Adil et al., 2025). Positivism, with its emphasis on objectivity, measurement, and causal relationships, is well-suited for research questions that seek to establish universal laws or test hypotheses. Positivism's ontological stance assumes an objective, measurable reality that exists independently of human perception (Dhobi, 2023). Positivist epistemology emphasises neutrality and objectivity, seeking to minimise researcher bias and ensure that knowledge is based on empirical evidence (Belharar et al., 2023).

5.4 Philosophical concepts within a paradigm

A research paradigm is a foundational philosophical framework or worldview that guides and shapes the entire research process, including how reality is perceived, how knowledge is acquired, and how research is conducted (Buriro et al., 2021). It comprises core beliefs, assumptions, and values that influence the choice of research questions, methodology, data collection, analysis, and interpretation (Adil et al., 2025). The present research is guided by an interpretivist paradigm, recognising that knowledge is socially constructed through interaction with participants and institutional documents.

As explained, a methodology is the overall approach to a research design, guiding how one finds answers to a research question (Williams, 2021). This approach is not chosen in isolation; it is a direct result of clarifying the study's underlying philosophy, which is its ontological and epistemological perspectives. Once this philosophical foundation is established, the appropriate research methods can be selected to align with the study objectives (Williams, 2021).

Common qualitative methodologies include ethnography, grounded theory, and phenomenology (Ataro, 2020). Phenomenology, for instance, focuses on understanding how individuals experience the world. It allows researchers to gain a deeper, more subjective understanding by exploring the lived experiences of their participants (Ataro, 2020; Buriro et al, 2021).

The core philosophical concepts that underpin a research paradigm include ontology, epistemology, and axiology, each of which provides a distinct perspective on the nature of reality, knowledge, and values, respectively (Dhobi, 2023). The ontology acknowledges multiple realities shaped by institutional roles, while the epistemology emphasises the co-construction of meaning through dialogue with stakeholders. Furthermore, ontology, at its essence, explores the nature of reality and existence, addressing fundamental questions about what exists, what categories these entities fall into, and the relationships between them. Epistemology, on the other hand, delves into the nature of knowledge, investigating how we acquire knowledge, what constitutes valid knowledge, and the limits of our knowing. Axiology, often less explicitly addressed but equally foundational, examines the role of values in research, acknowledging that research is not value-neutral and that researchers' values inevitably influence their choices and interpretations (Rashid et al., 2019).

5.4.1 The Ontological perspectives

Regarded as a fundamental branch of philosophy, ontology deals with the nature of reality, that is, what exists and what can be known about it, seeking to define what constitutes reality and the nature of things that exist (Dhobi, 2023). Different paradigms embrace distinct ontological stances, ranging from the positivist view of an objective, measurable reality to the constructivist perspective that reality is socially constructed and shaped by individual experiences (William, 2024). Ontological stances vary, ranging from realism or objectivism, which assert that a single, measurable reality exists independent of human perception. The ontological stances of relativism or constructivism view reality as multiple, socially constructed, and context-dependent (Dhobi, 2023).

Scholars define ontology as a formal representation of knowledge that defines concepts, their relationships, and other domain-specific information (Pretorius, 2024; William, 2024). Among the primary elements of an ontology are Concepts or Classes representing the main formalised elements of a domain, often organised in a hierarchical structure. Relationships describe how concepts are

related to each other, including taxonomic (e.g., "is-a" relationships) as well as non-taxonomic ones (Pretorius, 2024). Individuals or Instances are specific examples of concepts, representing real-world entities within the domain. Then, Attributes refer to the properties or characteristics associated with concepts or individuals. Lastly, Axioms are the formal statements that describe the meaning and relationships between concepts, ensuring consistency and logical correctness (William, 2024).

Belharar et al. (2023) argue that quantitative research can be viewed as a research strategy rooted in the ontological principle and philosophy that truth and reality are free from the observer's influence. Belharar et al. (2023) note that the ontological perspective involves exploring the "very nature" of things in the social world (i.e., "What is your ontological position or perspective?"). The concept of ontology can be complex, as the nature and essence of social phenomena can often seem fundamental and obvious, making them challenging to conceptualise (Belharar et al., 2023). William (2024) reinforce this notion by defining ontology as a direct formal specification of a theory of interest.

5.4.2 The Epistemological perspectives

Epistemology is another cornerstone of philosophy, which explores the nature of knowledge and how it is acquired. Moreover, it examines how we know what we know and the relationship between the knower and the known, as well as what can be known (Pretorius, 2024). Different paradigms propose differing epistemological positions, spanning from the positivist emphasis on objective observation and empirical evidence to the interpretivist focusing on the understanding of subjective meanings and interpretations (William, 2024).

Across paradigms, epistemological stances vary, as Positivism emphasises objective knowledge acquired through empirical observation and experimentation, while constructivism emphasises the subjective construction of knowledge through social interaction and interpretation. For qualitative research, emphasis is on the quality of information rather than quantity (Dhobi, 2023). The researcher and the participant can be independent of each other (Dhobi, 2023). Epistemology concerns the nature and scope of knowledge, specifically how knowledge about reality can be acquired and validated. It explores whether knowledge is objective and quantifiable or subjective and co-constructed between the researcher and participants.

5.4.3 The Axiological perspectives

Axiology, within a research philosophy, refers to the study of beliefs and values, it addresses the role of beliefs and values in research. While often less explicitly discussed, it considers the role of values in the research process, recognising that research is not value-free and that the researcher's beliefs and values are able to influence the research questions, methods, and interpretations (Rashid et al.,

2019). Furthermore, it shapes the research process and influences the interpretation of findings (Dhobi, 2023). In essence, axiology addresses the ethical and moral dimensions of research by guiding how values influence the design, conduct, and outcomes of a study, including the researcher's stance on issues such as social justice, equity, and the welfare of participants. Understanding these core philosophical concepts is key for a researcher to successfully evaluate their own assumptions, align the research methods with the philosophical stance, and ensure the rigour and integrity of the research (Rashid et al., 2019).

In qualitative research, axiology acknowledges that research is value-laden, meaning that a researcher cannot be fully separated from the study in terms of their beliefs, values, and biases. The lack of separation inevitably influences all stages from problem formulation to data interpretation. For instance, interpretivist and constructivist paradigms accept that knowledge is co-constructed and shaped by values. Researchers are, therefore, encouraged to practice reflexivity, critically reflecting on how their values impact the inquiry, and to maintain transparency about these influences to enhance research trustworthiness (Nkambule and Ngubane, 2023).

5.5 Research approach

Creswell and Creswell (2018) designates research approaches as procedures and plans that unify the research stages from general assumptions to more thorough methods of data collection, analysis, and interpretation. The three most common research approaches recognised are quantitative, qualitative, and mixed-methods research. Table 5.1 summarises research approaches.

Table 5.1: Research approaches, strengths, and weaknesses

Research approach	***Strengths***	***Weaknesses***
Qualitative	• Provides rich, in-depth insights into complex processes, contexts, and perspectives. • Flexible; allows exploration of emerging themes and new directions. • Captures detailed, human-centred data (e.g., through interviews, focus groups).	• Findings not easily generalisable. • Data collection and analysis are time-intensive. • Subjectivity and potential researcher bias. • Replication is challenging. • May lack credibility among policymakers who prefer statistical data.

	• Valuable for exploring new phenomena, theory building, and contextual understanding. • Cost-effective for small, targeted studies.	
Quantitative	• Enables statistical generalisation to larger populations. • Standardised, objective, and replicable data collection. • Efficient analysis with large datasets. • Useful for theory testing and hypothesis validation. • Measures phenomena not directly observable.	• Limited depth in understanding context or motivations. • Vulnerable to sampling and measurement biases. • Rigid methods may miss unanticipated phenomena. • May ignore subjective experiences. • Requires large sample sizes for reliability.
Mixed methods	• Integrates breadth (quantitative) and depth (qualitative). • Offsets weaknesses of individual approaches. • Enables triangulation and validation of findings. • Flexible and adaptable to complex research problems.	• Subject to sampling challenges from both approaches. • Requires more time, funding, and resources. • Complex data integration and interpretation. • Needs expertise in both methods. • Logistically demanding to design and execute.

The present study adopts a qualitative research methodology firmly grounded in a constructivist-interpretive paradigm to address its exploratory and descriptive research questions. The constructivist-interpretive paradigm recognises that knowledge and understanding are actively

constructed through social interactions, interpretations, and dialogue rather than passively reflecting an objective reality (Miles, Huberman and Saldaña, 2019; Dhobi, 2023). This philosophical stance aligns with a relativist ontology and subjectivist epistemology, asserting that reality is multiple, context-dependent, and co-created through participant-researcher interactions (D'Cruz, Timbrell and Watson, 2016). Knowledge and understanding are co-created through dialogue, interaction, and interpretation rather than discovered objectively.

Given the exploratory and descriptive nature of the research questions, which focus on understanding how SDT strategies are explored, assessed, and implemented in South African TVET colleges, it necessitated an approach capable of capturing nuanced, context-rich, and subjective perspectives. A qualitative approach is well-suited to investigate how diverse stakeholders (e.g., lecturers, administrators, MIS and ICT managers) interpret and ascribe to DT phenomena within their institutional settings (Hervás-Gómez, Díaz-Noguera, Guijarro-Cordobés and Gallardo-Pérez, 2020; Niță and Guțu, 2023).

The present study employed an interpretive case study design, enabling a comprehensive exploration of the organisational, cultural, and social dynamics influencing SDT implementation within the complex context of TVET colleges (Mtshali et al., 2020). Multiple qualitative methods, such as semi-structured interviews, focus group discussions, and document analysis, were employed to triangulate data and enrich understanding. These qualitative methods provide rich, descriptive data that capture the lived experiences and nuanced perspectives of multiple stakeholders (Jeza and Lekhanya, 2022). Supporting inductive, idiographic analysis identified emergent themes and patterns (Wong, 2014; Guest, Namey and Chen, 2020).

This approach permits inductive, ideographic analysis through a dynamic, creative process of coding and theorising, emphasising meaning-making and the identification of emergent themes and patterns beyond what quantitative methods typically reveal (Wong, 2014; Guest et al., 2020). The selected paradigm and design align directly with the research questions (see Chapter One), which required unpacking complex institutional, pedagogical, governance, and policy-related processes. For instance, to address how digital tools are used (Sub-RQ2) or how leadership practices affect SDT (Sub-RQ3), a constructivist lens offered insight into participant meaning-making. Similarly, questions regarding barriers or enablers (Sub-RQ1) and challenges in under-resourced contexts (Sub-RQ4) were best explored through context-sensitive, interpretive methods. Moreover, qualitative research's inherent flexibility allowed for uncovering unexpected barriers (e.g., infrastructure deficits, digital literacy deficits) and unplanned enablers (e.g., supportive leadership, innovative practices). These unplanned enablers and unexpected barriers influence the success or failure of DT

efforts, which are often invisible in structured or quantitative approaches (Ramorola, 2018; Türk, 2023).

Philosophically, the present study explicitly considered foundational assumptions around ontology, epistemology, and axiology to ensure coherence between the research aims, methodology, and methods (Miles et al., 2019; Dhobi, 2023). This alignment guaranteed that the study not only explored "what" and "how" SDT occurs but also uncovered the "why" by delving into subjective interpretations, experiences, and social constructions. This methodological stance is also informed by axiological considerations, acknowledging the researcher's role and values in co-constructing meaning. The approach prioritises participant voice, equity, and contextual understanding, consistent with the study goal to contribute actionable knowledge for inclusive SDT policy and practice (Manda and Backhouse, 2018; Parua and Yang, 2024).

Knowledge generated through this qualitative inquiry aims to inform the development of equitable and effective DT policies and intervention strategies that address persistent challenges such as digital skill disparities, talent deficits, and digital divides within the TVET sector (Manda and Backhouse, 2018; Parua and Yang, 2024). Through prioritising depth, context, and participant voices, the present study offers important insights for fostering inclusive and sustainable digital advancement in education. Thus, reinforcing the appropriateness of the selected approach for capturing the complexity of DT within public education systems.

The development of conceptual models for SDT often relies on qualitative grounded theory methodologies. When aiming to develop a theory grounded in participant data, Grounded Theory is a viable approach (Charmaz, 2014). This involves iterative coding (open, axial, and selective) to analyse systemic challenges and design actionable frameworks. For instance, the present study emphasises the need for structured blueprints to align DT with sustainability goals, ensuring operational effectiveness without resource burnout (Mohamed Hashim et al., 2022b). The qualitative research approach involves developing theories based on data rather than testing existing theories. The approach helps institutions identify intangible influences, such as leadership dynamics and policy gaps, through data-driven insights. Furthermore, it is particularly useful when little prior research exists on a topic, allowing new concepts, patterns, and relationships to emerge directly from the data.

5.6 Research Strategy

To achieve the study objectives and address the core research question, a qualitative research methodology grounded in the constructivist-interpretive paradigm was employed. This approach is particularly well-suited to developing an in-depth understanding of the complex, socially constructed

realities of SDT within South African TVET colleges. The chosen research strategy is a case study, which is an inductive approach designed to develop a theory or conceptual framework directly from the data. A case study strategy is preferred over phenomenology because the study seeks to generate theory directly from participants' experiences and institutional contexts, rather than only describing lived experiences (Buriro et al., 2021). This approach is particularly relevant given the limited prior research on SDT within the TVET sector (Mohamed Hashim et al., 2022b). The strategy allows new concepts, relationships, and practical strategies aligned with the study objectives to emerge from participants' insights. The research process follows an iterative cycle of data collection and analysis, with open, axial, and selective coding to identify and refine emergent themes.

Each procedural step has been designed to ensure comprehensive coverage of the four research sub-questions. Purposive sampling and differentiated interview protocols ensured that barriers, enablers, practices, and readiness are examined across multiple institutional levels. Document analysis ensured policy alignment. The case study iterative coding process ensured that the resulting framework is firmly rooted in empirical evidence and existing theories, making it both theoretically robust and practically applicable.

5.6.1 Selection of the research site

The broader population relevant for the present study comprised all South African public TVET colleges. However, the specific focus was on the institutions previously identified for DHET initiatives to integrate sustainability into the TVET sector (Singh and Feuerriegel, 2013). This initiative initially began as a pilot under the S4GJ (Skills for Green Jobs) programme and was later expanded to all public TVET colleges (Freimann and Magnus, 2023). From this targeted group, the following seven colleges were initially considered: Boland TVET College, Central Johannesburg TVET College, Eastcape Midlands TVET College, Northlink TVET College, Northern Cape Rural TVET College, Port Elizabeth TVET College, and Umfolozi TVET College. These institutions represent diverse geographic and socio-economic contexts across South Africa. For the present study, data were successfully collected from five of these colleges. Regrettably, two institutions declined participation due to having already approved too many research activities, making it unfeasible to accommodate additional research at the time of the present study. The data gathered from the participating colleges directly addressed the study goal and the primary research question: "How should sustainable digital transformation strategies and initiatives be evaluated and enhanced, in the context of South African higher education institutions?"

5.6.2 Sampling strategies

In qualitative research, selecting a sample frame starts by identifying individuals who are most suitable to participate, based on the specific research question being addressed (Denieffe, 2020; Williams, 2021). According to Denieffe (2020) participants should ideally have relevant exposure or experience with the subject matter under investigation. Campbell, Greenwood, Prior, Shearer, Walkem and Young (2020) further explains that when researchers aim to learn about a large population, such as students or vehicles, it is often impractical to involve every member due to time and cost constraints. The practical approach, therefore, is to gather data from a subset of the population, with the expectation that the sample will be representative of the whole group.

If the information obtained from this subset reflects what would have been gathered from the entire population, the researcher can confidently make inferences and draw conclusions generalisable to the broader group. This procedure of choosing a smaller portion from a larger population to study is known as 'sampling' (Campbell et al., 2020).

Qualitative research prioritises depth of understanding over statistical generalisability, making the choice of sampling method foundational to the study's credibility and richness of insight (Joseph et al., 2024; Nkala et al., 2024). For the present study, a stratified purposive, non-probability sampling approach was employed to ensure the inclusion of key stakeholders central to the implementation and governance of SDT strategies. Participants were selected based on their roles and responsibilities in ICT infrastructure, academic leadership, curriculum delivery, and institutional management. Stratified purposive sampling was deemed the most appropriate for selecting MIS, ICT, and Campus managers, as well as Post-levels 2 or 3 lecturers from the specified TVET colleges. Aiming for data saturation, not a fixed sample size, diversity and ethical rigour were ensured throughout the process (Saunders et al., 2023). The technique yielded rich, credible insights into SDT strategies in South African TVET institutions.

In qualitative research, the selection of a suitable sampling method constitutes a cornerstone of the entire investigative process, markedly influencing the depth, richness, and overall credibility of the findings (Omona, 2013). Unlike quantitative studies that prioritise statistical generalisability through random sampling techniques, qualitative research is primarily concerned with achieving an in-depth understanding of specific phenomena within a particular context (Dhobi, 2023). Given the specific characteristics of the target sample frame, which includes MIS, ICT, and Campus managers who were selected for individual interviews, alongside Post-level 2 and 3 lecturers who participated in focus group discussions across seven pre-selected TVET colleges, a purposive, non-probability sampling approach was deemed the most appropriate sampling choice (Al-Busaidi, 2008). This technique is

particularly well-suited to qualitative research designs, where the goal is not to generalise findings to a larger population but rather to gain rich, detailed insights from individuals or groups who possess specific knowledge, experiences, or perspectives relevant to the research question (Johnson, Adkins and Chauvin, 2020).

5.6.2.1 Purposive sampling

Purposive Sampling is defined as deliberately selecting the participants based on their roles, expertise, and relevance to the research question (Campbell et al., 2020). Purposive sampling was used to select participants who were directly involved in SDT initiatives at each college. The use of purposive sampling enabled the data to come from those with the most relevant experience and insight into the phenomenon under study (Delubom and Marongwe 2022).

Purposive sampling, also known as purposeful sampling, is a strategic technique widely employed in qualitative research to select participants who can provide the most relevant and informative data to address the study objectives (Doyle, Catherine, Brian, Annemarie and McCann, 2020). The method diverges from probability sampling, which aims to obtain a representative sample of the entire population, and instead focuses on the intentional selection of individuals or groups based on predefined criteria or characteristics (Robinson, 2014). The decision to employ purposive sampling in this context reflects a commitment to maximising the informational yield from a relatively small group of participants. Through carefully selecting participants based on their roles, experience, and expertise within the TVET college system, the present study gathered in-depth perspectives on the specific issues under investigation. Using a co-design approach to identify a purposive sample can ensure the research findings are viewed as credible by stakeholders (Denieffe, 2020).

Purposive sampling has been extensively used across research disciplines, particularly in business and management studies (Aguinis, Ramani and Alabduljader, 2018). Such a sampling technique empowers researchers to strategically identify informants with unique insights into the subject matter, thereby amplifying the depth and richness of the gathered data. As researchers deliberately select participants who can offer the most relevant data, it enhances the trustworthiness of data collection and analysis (Campbell et al., 2020).

5.6.2.2 Stratified purposive sampling

Stratified purposive sampling is denoted as further dividing the sample into subgroups known as strata to ensure representation across key categories, such as colleges and lecturer levels (Campbell et al., 2020). This sampling strategy involved selecting at least one MIS, ICT, and Campus Manager per college for individual interviews, and at least two lecturers from both Post-levels 2 and 3 for organised

focus groups within each institution. The use of this sampling technique guaranteed diversity and coverage across all the targeted college categories (Campbell et al., 2020).

The selection of MIS, ICT, and Campus managers for individual interviews was driven by their unique positions within the TVET colleges. These individuals are directly responsible for the management, implementation, and maintenance of the technological infrastructure that supports the colleges' educational and administrative functions. Their perspectives are key to understanding the challenges and opportunities associated with technology adoption, integration, and utilisation in the TVET sector. Their insights into the practical aspects of technology management, as well as their understanding of the needs and challenges faced by both students and faculty, made them valuable informants for the present study. Semi-structured interviews were used to explore the factors under study (Algassim, Sepasgozar, Ostwald, and Davis, 2023). In engaging with these key stakeholders, the present study gained a comprehensive understanding of the technological landscape in TVET colleges and identified areas for improvement and innovation.

5.6.2.3 Focus group sampling

For the focus group sampling, participants were selected to represent a range of perspectives within the lecturer population. These lecturers represent an important group of lecturing staff who are actively involved in delivering vocational and technical education to students. Through bringing together lecturers from different disciplines and departments, the focus group discussions elicited diverse perspectives on teaching practices, curriculum delivery, and student engagement. The participating lecturers were from both Post-levels 2 and 3, ensuring representation from each college. Post-level 2 is a mid-level Subject Head or Senior Lecturer, while Post-level 3 is a Senior or Head of Department educator in South African public TVET colleges under the DHET. There were six to eight participants per focus group for optimal interaction and data richness. The focus group sampling technique ensured the exploration of shared and divergent experiences among lecturers, enhancing the depth and validity of the findings (Joseph et al., 2024).

5.6.2.4 Sample Size Considerations

A well-defined sampling plan is vital for the credibility and success of any qualitative study. Table 5.2, the Sampling Plan, outlines the specific participant groups, sampling methods, and target sample sizes for the present study. These choices were driven by a clear rationale designed to ensure the collection of rich, relevant data from key stakeholders. The two main goals of this sampling technique were to obtain expert insights and to capture diverse perspectives on SDT strategies.

Table 5.2: Sampling Plan

Participant Group	Sampling Method	Target per College	Total (7 Colleges)
MIS or ICT Campus Managers	Purposive (individual)	1-2	7-14
Post-levels 2 or 3 Lecturers	Stratified purposive	6-8 per focus group	42-56

5.6.3 Selection of participants

For the present study, participant selection focused on identifying individuals who could provide the most relevant data (Neumeyer and Liu, 2021). The present study used purposive sampling, a non-probability technique that involves deliberately choosing participants based on their specific traits and expertise (Delubom and Marongwe, 2022). This technique was adopted because the present study assumed that certain categories of participants, due to their theoretical understanding and direct experience with the topic, would offer unique and important perspectives on the phenomenon under investigation (Doyle et al., 2020).

The decision to conduct individual interviews with managers and focus groups with lecturers reflects a data collection technique tailored to the specific roles and responsibilities of each group. Individual interviews are well-suited for gathering in-depth perspectives from individuals who hold unique knowledge or expertise (Ismail, khuzaineyi, Mohd Nopiah, and Mohd Sattar, 2018). This format allows for a more personalised and nuanced exploration of individual experiences and opinions. Focus groups, on the other hand, are particularly effective for exploring shared beliefs, values, and attitudes within a group (Hovlid, Husabø, Valestrand and Hartveit, 2022).

For a comprehensive case study on SDT in South African TVET colleges, the ideal participants were a representative of a diverse cross-section of stakeholders with strategic, operational, and pedagogical insights into SDT. The inclusion criteria were set at a minimum of one year of service and at least one year of involvement in decision-making, implementation, or teaching related to DT. Table 5.3 presents a breakdown of ideal participant categories, the rationale behind them, and the corresponding interview formats.

Table 5.3: Participant Categories

	Role	Format	Notes
1.	MIS Managers	Individual Interview	Key for governance, data, analytics
2.	ICT Managers	Individual	Technical depth,

	Role	Format	Notes
		Interview	infrastructure
3.	Campus Managers	Individual interview	Administrative insight, leadership vision
4.	Post-Level 2 & 3 Lecturers	Focus Group	Rich dialogue on teaching, resistance, and innovation

Campus managers or Centre managers are responsible for operational leadership at the campus level, policy implementation, and resource allocation. Individual interviews were conducted with them, as they have insight into topics such as governance, resource allocation, leadership vision, funding strategies, institutional culture, and change management. Furthermore, these participants have a holistic view of the institution, balancing academic functions with administrative and infrastructural realities.

For the technical aspect of the study, individual interviews were conducted with MIS (Management Information Systems) managers. These managers were central to understanding the technical infrastructure, data management, security, and the practical challenges of implementing new systems. These managers are tasked with overseeing data systems, digital infrastructure, and analytics, which are significant for evaluating SDT success and governance. Moreover, these participants possess knowledge of infrastructure, data governance, administrative DT, KPIs, and systems integration.

Similar to MIS managers, the IT (Information Technology) managers or Information and Communications Technology (ICT) Coordinators provided detailed insights into hardware availability, network reliability, technical support structures, and the day-to-day infrastructural barriers and enablers, together with keen insight into infrastructure readiness, support systems, cybersecurity, digital literacy support, and scalability issues. These managers oversee the technological backbone, including hardware, software, and networks, and are deeply involved in the implementation process.

The Post-level 2 and 3 Lecturers (Senior Educators) are frontline implementers of digital tools in teaching and learning, and they effectively addressed topics related to student engagement and pedagogical shifts. As primary users of digital tools in a pedagogical context, these educators had insight into digital literacy, effectiveness of CPD and support, as well as Shared cultural attitudes towards innovation and resistance.

Since each stakeholder group plays a distinct role in the DT ecosystem within a TVET college, differentiated qualitative interview schedules were thus developed, tailored to each stakeholder group's responsibilities, experiences, and perspectives.

5.7 Role of the researcher

The researcher's role is foundational in qualitative inquiry, collecting quality and ethical data that meet the requirements of the study (Nkambule and Ngubane, 2023). Within a case study strategy, the role extends beyond simply gathering data to include constant comparison, theoretical sampling, and iterative coding. This central position necessitates a high degree of transparency and being critically reflexive about personal assumptions, positionality, and how these may shape data interpretation (Vlachopoulos et al., 2023).

In the present study, the researcher was solely responsible for the entire interview process, from designing the interview schedules, ensuring alignment with the research questions and objectives. Interviews and focus groups were conducted in person, thereby maintaining consistency in data collection. Furthermore, recording and transcribing all interviews and discussions ensured accuracy and maintained confidentiality and voluntary participation. Participants were consistently reassured that all information would be handled confidentially and explicitly informed of their right to withdraw from the session at any time without consequences (Vlachopoulos et al., 2023). The technique prioritised participant comfort and autonomy, fostering an environment of trust essential to gathering rich, authentic data. The direct involvement allowed for a deep, firsthand engagement with the data.

Following the data collection phase, the present study proceeded with the analysis, taking sole responsibility for interpreting the findings. While the researcher's professional familiarity with the South African TVET context provided valuable contextual understanding, it also required deliberate reflexivity to minimise potential bias. Throughout this process, a reflective stance was maintained, with transparency about methodological decisions and interpretations being a core principle, as recommended for high-quality qualitative research (Nkambule and Ngubane, 2023). A reflective journal was maintained throughout the study to document decision-making, emerging insights, and any shifts in interpretation. A constant-comparison approach was applied across stakeholder groups to avoid privileging any one perspective. Moreover, triangulating interview data with document analysis reduced the influence of individual researcher interpretation.

In explicitly acknowledging these positional dynamics and applying systematic case study procedures, the study ensured that findings emerged from the data rather than pre-existing assumptions.

5.8 Data collection instruments

The choice of data collection instruments was guided by the research objectives and questions, as well as the need for rich, comparative insights across institutional roles, done in line with the three main sources of qualitative data being interviews, observations, and documents (Prior, Mather, Ford, Bywaters and Campbell, 2020). To understand the multifaceted nature of SDT and its impact, a multi-method approach was employed, leveraging semi-structured interviews, focus group discussions, and document analysis, which are well-established and vibrant methods in qualitative research scholarship.

Individual interviews were best suited for participants who hold strategic, high-level positions. The format allowed the present study to delve deeply into confidential or complex topics, such as policy, funding, and leadership vision. This combination allowed for the collection of rich, thick descriptions that are not attainable through closed-ended surveys (Sharma, 2023). Observation of ICT resource usage patterns was not undertaken due to access and ethical constraints; instead, usage patterns were explored indirectly through interviews and documents.

5.8.1 Interviewing

A case study places a premium on the quality of information gathered, as opposed to mere quantity, and interviews are a cornerstone of this strategy, enabling researchers to delve into participants' experiences, interpretations, and meanings (Dhobi, 2023). Interviews remain a core data collection method and are particularly valuable in case studies for uncovering processes, interactions, and meanings. The adoption of interviews as a data collection method underscores a commitment to capturing the lived realities of individuals and groups within their natural settings, and the researcher aims to interpret the phenomena through the lens of the meanings participants ascribe to (Dhobi, 2023). The use of interviews allows for the collection of varied empirical materials such as cases, personal experiences, and interactions (Dhobi, 2023).

The interview schedule depends on the methodology; semi-structured questions with prompts may be more valuable for eliciting narratives from participants (Prior et al., 2020; Dhobi, 2023). Semi-structured formats enable researchers to follow a flexible guide while probing for in-depth information. This adaptability is fundamental for gaining a holistic understanding of the research topic, as it allows for the exploration of unforeseen avenues and the clarification of ambiguous or incomplete information. A semi-structured interview typically consists of a dialogue between the researcher and the participant (Sharma, 2023).

5.8.1.1 Structured interview schedule

Structured interviews facilitate consistency between participants, offering structured questionnaires where interviewers are trained to ask questions in a standardised manner (Dhobi, 2023). Structured interviews, where all participants are asked the same questions in identical conditions, can aid comparability. A structured interview ensures that all participants address the same fundamental themes and topics, providing a common ground for analysis and comparison (Algassim et al., 2023). The rigorous employment of uniform data collection procedures exerts a noteworthy influence on the resultant outcomes of investigations (Ahmed, 2024). Although fully structured interviews were not used, the present study's interview guide was meticulously crafted to uphold uniformity in the fundamental inquiries posed to each participant (Sharma, 2023).

5.8.1.2 Semi-structured interview schedule

Sharma (2023) posits that semi-structured interviews can elicit rich, nuanced narratives from participants, thereby facilitating a comprehensive understanding of the intricate phenomena under investigation. Furthermore, Sharma (2023) states that, conversely to fully structured interviews, which adhere to a rigid script, semi-structured interviews provide the researcher with the latitude to adapt their questioning based on the participant's responses, facilitating a more natural and conversational exchange.

Semi-structured interviews, the most common type of interview in qualitative research, involve the use of a pre-determined interview guide while allowing the researcher the flexibility to probe for deeper insights or seek clarification when necessary. Semi-structured interviews involve the use of an interview guide that contains themes and questions, but the interviewer can modify the order or wording of questions to tailor them to the specific context and participant. This iterative approach allows for the refinement of the research questions and the development of new hypotheses based on the emerging data (Prior et al., 2020).

The primary interview format in the present study was semi-structured, with open-ended questions to encourage rich descriptions and the emergence of unanticipated themes. The same core set of questions was posed to all participants, but follow-up questions varied depending on the responses. Interviews with MIS managers and ICT managers explored technical infrastructure, data governance, and the practical challenges of implementing new systems. Interviews with Campus managers explored strategic leadership, resource allocation, and policy alignment with the SDT. These interviews were conducted online via Microsoft Teams, which facilitated recording and subsequent transcription, and were scheduled at times convenient for the participants. They were recorded with their consent.

5.8.1.3 Focus group interview schedule

Focus groups are a valuable method for gathering qualitative data. The method encouraged participants to build on each other's ideas, providing a deeper exploration of issues and potentially uncovering new insights that might not emerge in individual interviews (Segú-Odriozola, 2025). Interviews were held with Post-Level 2 and 3 lecturers to examine digital pedagogy, training needs, and lecturing practices in blended and online learning contexts. The interactive nature of focus groups enables researchers to observe how participants collectively negotiate and construct meaning, providing valuable insights into shared beliefs, values, and attitudes. To ensure the interview questions were both appropriate and aligned to the objectives and research questions, a pilot focus group interview was conducted before the actual data collection (Alqahtani, Al-Nasser, Alzahem, and Alqhtani, 2025). The emphasis on Post-level 2 and 3 lecturers ensured that the focus group discussions captured the perspectives of experienced educators with a deep understanding of the challenges and opportunities within the TVET sector (Makgati and Awolusi, 2020).

5.8.2 Document analysis

Complementary to the stated primary data collection method, document analysis (e.g., policy documents, strategic plans, reports) provided contextual background and corroborating evidence. Document analysis is a systematic approach to evaluating electronic materials (e.g., Internet-transmitted or computer-based materials) and/or printed materials (e.g., hardcopy books). This distinct data collection method is separate from interviews and yet plays a foundational role in validating and contextualising data gathered from interviews and focus groups (Rêgo, Jayantilal, Ferreira and Carayannis, 2023). This analysis involved the thorough examination of institutional documents, such as ICT policies, digital strategies, and SDT action plans, to gain deeper insights into the research topic (Morgan, 2022). As the document analysis progresses, potential connections between themes emerge, guided by existing literature and the conceptual research framework, leading to a deeper understanding of the subject matter (Kayesa and Shung-King, 2021). This iterative process necessitates researchers to repeatedly rework the data using mind maps, charts, and tables as cognitive tools, facilitating the discovery of meaning and coherence within the evolving research landscape (Korachi and Bounabat, 2019).

For this present study, document analysis served as an integral method for understanding SDT strategies within the context of TVET colleges. The analysis included Institutional Strategic Plans of selected TVET colleges, DHET and TVET college research reports, the TVET Colleges Strategic Plan 2021-2030, and the National e-Education Policy Framework, all of which were analysed to validate and contextualise interview and focus group data.

5.9 Data management

Following data collection, a meticulous data management process was implemented. This involved transcribing all online-recorded interviews and focus group discussions. To uphold the principles of privacy and confidentiality, all transcribed data underwent thorough anonymisation, removing any identifiable personal or institutional information. The anonymised data were then prepared for systematic coding.

5.9.1 Data recording

Data from the interviews and focus groups were recorded and stored on a Microsoft Teams channel. To ensure the accuracy and authenticity of participant responses during analysis, the present study also took field notes as further backup. The field notes were especially useful for capturing impressions, environmental contexts, and non-verbal cues that audio recordings may have missed (Ataro, 2020). This helped to mitigate any fear of losing valuable data. All collected documents and data were stored in password-protected digital folders, and any identifiable information was anonymised before analysis to ensure participant confidentiality.

5.9.2 Verbatim transcription

Verbatim transcription of interview responses is an important step in qualitative research, serving not only to convert spoken data into text but also to familiarise the researcher with the content. Transcriptions of interview responses commenced immediately after each interview and were conducted manually by the researcher (Hill, Tawiah-Agyemang, Kirkwood and Kendall, 2022). This approach was chosen due to budgetary constraints.

The benefits of manual transcription include direct involvement in the transcription process. This ensured that the researcher became thoroughly acquainted with the data, which is important for subsequent analysis and interpretation (Hill et al., 2022). Accordingly, the hands-on engagement allows researchers to immerse themselves in the data, fostering a deeper understanding of the participants' perspectives and the nuances of their responses.

To enhance familiarity, the present study repeatedly listened to the original interviews and consulted field notes throughout the transcription process (Hill et al., 2022). This iterative engagement helps identify patterns, themes, and significant insights within the collected data. This detailed transcription process, especially because it was done manually, contributed significantly to the intimate knowledge of the data, which is invaluable for robust qualitative analysis.

5.10 Analysis of data

An inductive coding process was employed, guided by principles of case study and interpretive inquiry (Mohamed Hashim et al., 2022a). To interrogate how SDT strategies are explored and assessed in South African TVET colleges. The analytical method was designed to address the primary research question and provide nuanced responses to the sub-research questions by identifying key patterns, barriers, enablers, and institutional dynamics related to SDT. Data analysis followed an iterative coding process, involving open, axial, and selective coding.

All interview recordings were transcribed verbatim and reviewed alongside field notes to ensure data accuracy and participant voice authenticity (Williams, 2021; Nkambule and Ngubane, 2023). To ensure accuracy, the present study carefully reviewed each transcript against the original recordings. Errors in transcripts were corrected, and all identifying details were anonymised to uphold the ethical principle of anonymity. All identifying information was removed and replaced with codes before coding using the qualitative data management software, ATLAS.ti 25 Windows, which facilitated efficient pattern identification and categorisation. Transcribing interview recordings verbatim and reviewing them alongside field notes is a robust practice that markedly enhanced the quality, accuracy, and trustworthiness of data (Williams, 2021; Hill et al., 2022).

Open coding involved an initial granular examination of interview and focus group transcripts to identify emergent concepts related to DT in teaching, learning, and governance. Axial coding then focused on establishing relationships between these categories, building a more coherent understanding. Allowing grouping into thematic clusters, such as barriers, enablers, and institutional responses, was key to answering sub-question 1. Finally, selective coding synthesised the findings into overarching themes, facilitating integrative insights aligned with sub-question 2 and sub-question 3 (on leadership and governance) and informing sub-question 4 (on policy recommendations). This process facilitated a dynamic engagement with data, allowing for emergent patterns and interpretive insights that align with the study objectives and goals (Wong, 2014; Guest et al., 2020).

The data analysis combined inductive and deductive coding to ensure both emergent insight and theoretical grounding. This dual strategy enhanced credibility and confirmability (see Section 5.11), with findings grounded in participant experiences and literature-informed constructs relevant to curriculum integration, pedagogical shifts, and institutional governance, directly addressing sub-questions 1 to 3.

While ATLAS.ti 25 Windows supported the organisation and coding of data, the interpretation of meaning remained a manual, reflective, and human-driven task (Gupta, 2023). The present study

conducted multiple close readings of transcripts, comparing participant responses across stakeholder groups of MIS, ICT, Campus managers, and senior lecturers; thus, ensuring that interpretations remained contextually grounded and theoretically coherent.

5.10.1 Interpretation of data

Data interpretation was a continuous and reflective process. While ATLAS.ti 25 Windows software facilitated the systematic coding, sorting, and categorisation of qualitative data, the present study manually engaged in close, iterative readings, comparisons, and deep analysis of the coded text to imbue it with meaning (Gupta, 2023; Ñañez-Silva, Quispe-Calderón, Huallpa-Quispe and Larico-Quispe, 2024). The software serves as a tool to facilitate the process, but the interpretive work remains with the researcher. The iterative approach, in which analysis occurred concurrently with data collection, enabled the present study to focus on emergent concepts, patterns, and categories as they unfolded in the data. Through this cyclical process, the study systematically identified significant themes and connections that enriched the understanding of the phenomenon under investigation.

The conceptual research framework for the present study provided a lens for interpreting these patterns and connections, guiding the study in discerning the most important characteristics and associations within the collected data. Despite the availability of software tools, it remains fundamental that meaning-making in qualitative research is a human-driven and interpretive act, as software supports but does not replace analytical insight or reflexive engagement (Gupta, 2023).

The research embraced an iterative, cyclical data analysis method, consistent with best practices in qualitative inquiry. This meant that analysis began concurrently with data collection, which enhanced the present study's ability to focus on emerging concepts and categories (Gupta, 2023). Through this continual process, the present study systematically sought to establish the most important characteristics within the collected data, develop a deeper understanding of what the data were saying, and find patterns and associations to give it meaning (Williams, 2021). The final interpretation combined the software's structured capabilities with deep, reflective researcher analysis, ensuring a rich, contextually grounded understanding of the findings.

5.10.2 Development of themes and categories

The rigorous qualitative data analysis, as described in Section 5.9, analysed the raw data gathered from the respective semi-structured individual and focus group interviews and the document analysis. This culminated in the development of key themes and categories grounded in the study's conceptual research framework (see Section 4.5). These themes and categories, which are discussed in detail in Chapter Six, were fundamental for organising and grouping the raw data to directly address the study's goal, as discussed in Chapter One. The creation and identification of these themes, categories,

and subcategories were guided by the study's goal, enabling the present study to construct a clear, evidence-based discussion of its findings. Categorising the raw data according to the information presented in Table 5.4 helped the present study discuss its findings.

Table 5.4: Emergent Themes to Research Questions

Research Question	**Theme**	**Sub-Themes or Categories**
Primary Research Question: How should sustainable digital transformation strategies and initiatives be evaluated and enhanced in the context of South African higher education institutions?	1. Strategic Approaches to SDT	• Long-term vision and planning • Digital maturity models • Alignment with national digital skills agendas
ICT Managers	2. Institutional Capacity and Readiness	• Infrastructure gaps • Staff digital literacy • System integration challenges
Campus Managers	3. Change Management	• Resistance to change • Communication and stakeholder involvement
	4. Policy and Governance	• Policy implementation gaps • Role of leadership in SDT
	5. Pedagogical Shifts	• Digital tool integration • Student engagement through technology
Sub-question 1: What are the enablers (critical success factors) and the barriers influencing sustainable digital transformation strategies, in South African TVET colleges?	1. Institutional Capacity and Readiness	• Infrastructure constraints • Funding availability • Staff competencies
	2. Socio-Economic Disparities	• Connectivity issues • Rural vs urban disparities

Research Question	Theme	Sub-Themes or Categories
		• Student access to devices
	3. Leadership and Vision	• Strategic leadership • ICT policy coherence
Sub-question 2: What and how is technology used in TVET colleges to improve higher education, and what are the digital transformation implications for institutional governance?	1. Pedagogical Shifts	• LMS usage • Blended and hybrid learning models
	2. Administrative Innovations	• Digitisation of records • Online registration and assessments
	3. Teaching and Learning Innovation	• Open Educational Resources (OER) • Digital content development
Sub-question 3: How are the leadership and governance structures influencing digital transformation in the context of TVET colleges in South Africa?	1. Leadership and Governance	• Executive support • Distributed leadership • Stakeholder buy-in
	2. Policy Implementation	• Monitoring and evaluation • Alignment with DHET frameworks
	3. Cross-departmental Collaboration	• ICT, Academic, and MIS alignment • Communication gaps
Sub-question 4: How can digital transformation strategies and initiatives be evaluated and improved in the context of South African TVET colleges?	1. Policy and Strategy Recommendations	• DT frameworks • Stakeholder-informed policies
	2. Equity-Driven Interventions	• Bridging the digital divide • Support for under-resourced campuses
	3. Capacity Building and Training	• Continuous professional development (CPD) • Technical support models

The following maps emergent themes to the preceding research questions.

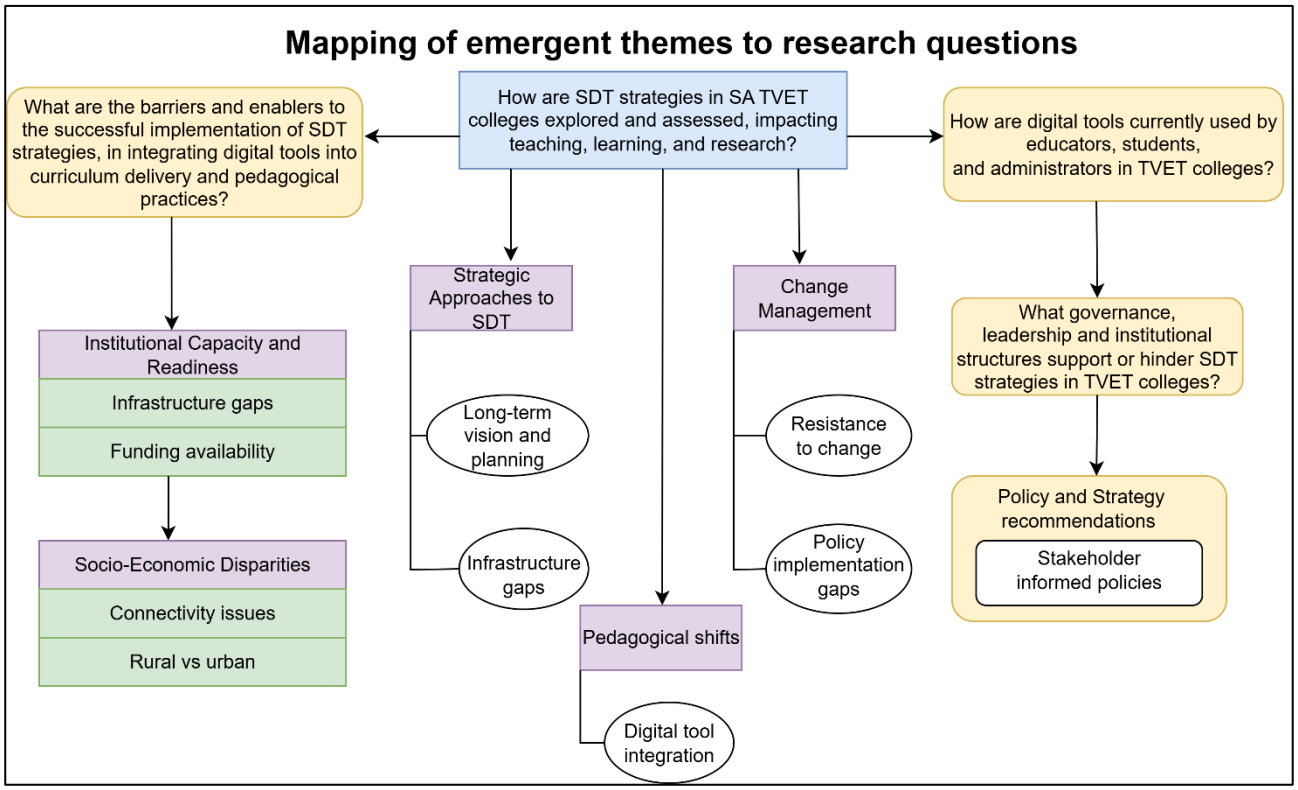


Figure 5.1. Mapping of Emergent Themes to Research Questions

Table 5.5 and Figure 5.1 are the visual alignment of the primary and sub-research questions with the key themes and sub-themes developed during the present study coding. Together, they illustrate how the raw data gathered for the present study, comprising the respective interviews and the reviewed documents, were systematically analysed and organised into emergent themes, categories, and sub-categories. Specifically, the conceptual research framework and the data analysis process led to the identification of themes and sub-themes aligned with the four research sub-questions.

Table 5.5: Main Themes, Categories, and Sub-Categories

	Theme	Category	Sub-Categories
1.	**Strategic Approaches to SDT**	Strategic Planning	• Long-term vision and planning • Digital maturity models • Alignment with national digital skills agendas
2.	**Institutional Capacity and**	Infrastructure & Resources	• Infrastructure gaps

	Theme	Category	Sub-Categories
	Readiness		• System integration challenges
		Human Capacity	• Staff digital literacy • Staff competencies
3.	**Change Management**	Organisational Culture	• Resistance to change • Communication and stakeholder involvement
4.	**Policy and Governance**	Policy Gaps & Implementation	• Policy implementation gaps • Monitoring and evaluation • Alignment with DHET frameworks
		Leadership and Vision	• Role of leadership in SDT • Executive support • Distributed leadership
5.	**Pedagogical Shifts**	Teaching Practice Transformation	• Digital tool integration • LMS usage • Hybrid or blended models • OER
		Student Engagement	• Student access • Technology-mediated learning
6.	**Socio-Economic Disparities**	Access & Equity	• Connectivity issues • Rural vs urban disparities • Student access to devices
7.	**Administrative Innovations**	Digitisation of Administration	• Online registration • Digital record-keeping • Assessment technologies
8.	**Cross-departmental Collaboration**	Institutional Integration	• Collaboration between ICT, Academic, and MIS units • Communication gaps

	Theme	Category	Sub-Categories
9.	**Capacity Building and Training**	Professional Development	• Continuous professional development • Technical support systems
10.	**Policy and Strategy Recommendations**	Equity-Driven Planning	• Bridging the digital divide • Under-resourced campus support
		Policy Formulation	• Stakeholder-informed strategies • Scalable DT frameworks

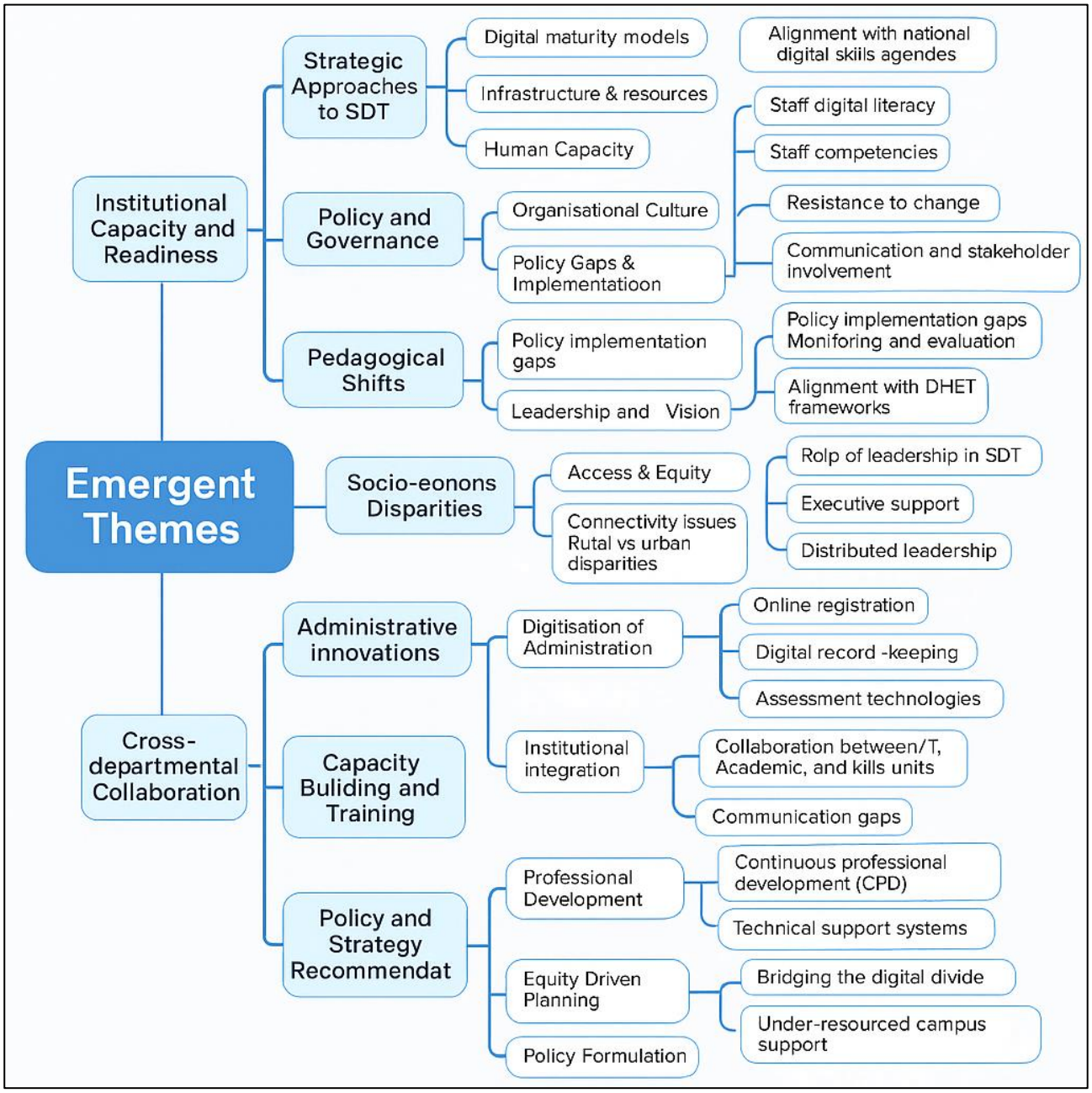


Figure 5.2: Extracted themes, categories, and sub-categories

Table 5.5 demonstrates how the raw data gathered for the present study (i.e., from the respective interviews and reviewed documents) were analysed and developed into themes and sub-themes**.**

5.10.3 Anonymity and confidentiality

Throughout the data analysis and reporting process, the present study prioritised the truthful representation of participant responses while ensuring their anonymity and confidentiality (Ataro, 2020). This was achieved through several measures, such as verbal assurances (Hill et al., 2022). Participants were assured from the outset that their contributions would be kept anonymous. Then, through data preservation, all gathered data was anonymised and kept confidential. The research findings and records do not contain any citations to individuals or specific groups. Instead, a system of codes was used to identify participants, ensuring their voices and opinions were accurately presented without compromising their identities.

5.10.4 Document analysis

This subsection describes how the data obtained from documents (Section 5.8.2) were analysed, focusing on the analytical techniques rather than the collection. Institutional documents such as ICT policies, digital strategies, and SDT action plans were analysed to validate and contextualise interview and focus group data.

Document analysis process is not merely a passive review of materials, but an active and iterative engagement with the data (Williams, 2021). The documents under scrutiny included the Institutional Strategic Plans of selected TVET colleges, DHET and TVET college research reports, the TVET Colleges Strategic Plan 2021-2030, and the National e-Education Policy Framework. The analytical approach allowed the present study to uncover hidden patterns, identify inconsistencies, and corroborate findings from other data sources, enriching the overall study outcomes (Williams, 2021). Document analysis can be effectively combined with various research methods, including interviews, observations, and quantitative analyses, enhancing its versatility and applicability in policy research (Williams, 2021). The systematic evaluation of documents ensured that the present study is grounded in empirical evidence and aligned with the broader policy context (Rêgo et al., 2023). Document analysis also helps in understanding the historical context and evolution of policies, providing a temporal dimension to the study. In examining policy documents, researchers are able to trace the development of ideas, identify shifts in priorities, and assess the impact of policy changes over time.

Thematic analysis coding was used to analyse the data, revealing three main themes: DT in education, educational efficacy and evolution, and overcoming barriers and embracing opportunities (Prosen

and Ličen, 2025). Each theme showed the progress, visibility, and requirements of DT (Williams, 2021; Abrahams, Moroe and Khoza-Shangase, 2023).

The TVET Colleges Strategic Plan 2021-2030 was analysed to provide insights into the progress and challenges of DT within these institutions (Nkambule and Ngubane, 2023). This plan provided a comprehensive overview of the strategic objectives and initiatives to integrate digital technologies into TVET colleges. It helped in understanding the current state of DT, pinpointing areas where progress has been made, and identifying the obstacles that impede further advancement. The National Infrastructure Plan 2050 and the National e-Education Policy Framework were also examined, providing a macro-level policy context for understanding the broader national strategies related to digital infrastructure and e-education (Kana and Letaba, 2024). Aligning educational paradigms with the imperatives of Industrial Revolution 4.0 offers a blueprint for navigating the new normal in higher education (Cadiz et al., 2024).

Effective implementation of DT requires robust technological infrastructure, innovative pedagogical approaches, and comprehensive policy and regulatory frameworks (Joseph et al., 2024). The integration of digital tools in educational institutions necessitates the adaptation of teaching resources to new technologies and has economic implications for implementing comprehensive digital education programs (Díaz-Suárez, Martín-Paciente and Travieso-González, 2025). In developing a qualitative model that advocates DT as a propelling force, institutions can build competitive advantages and a sustainable education management strategy (Mohamed Hashim et al., 2022a). Such alignment fosters a comprehensive and flexible framework for HEIs, bringing the institution closer to achieving its strategic goals, particularly in education and research (Alenezi and Akour, 2023). Digital transformation promotes significant changes, innovation, and automation in higher education. Institutions must have a clear digital vision, strategy, and leadership to champion the transformation, while also integrating emerging technologies to enhance operational efficiency and student experiences (Alenezi, 2023).

The DT encompasses curriculum enhancements, faculty training, infrastructure upgrades, and the cultivation of a digital culture, ensuring that the higher education sector remains competitive and relevant (Alenezi and Akour, 2023; Díaz-Suárez, Martín-Paciente and Travieso-González, 2025). It involves adopting emerging technologies, digitising processes and resources, and ensuring users stay up to date with the latest technological advancements (Recker, 2023). The need for SDT is driven by continuous technological advancements and their societal implications. Many organisations are starting to realise the importance of adapting their operational models to keep pace with changing technological advancements (Singun, 2025). Sustainable digital transformation strategies go beyond

adopting new technologies and require profound organisational changes to incorporate digital practices and capabilities sustainably (Gkrimpizi, Peristeras and Magnisalis, 2023).

Table 5.6 below summarises the relevance and relation of the analysed documents to the study.

Table 5.6: Documents analysed

Part	Documents analysed	Relation to the study
1.	**TVET Colleges Strategic Plan 2021-2030**	It provides insights into the progress and challenges of DT.
2.	**National Infrastructure Plan 2050** **National e-Education Policy Framework**	These provide the macro-level policy framework guiding DT and TVET operations in South Africa. As national and government policy documents.
3.	**DHET or TVET college research reports** **DHET ICT in education implementation guidelines**	These documents help assess implementation, institutional alignment, and strategic planning.
4.	**International or Donor-Funded Project Reports** • GIZ, COL, UNESCO, or S4GJ programme reports • Pilot programme documentation (on ICT integration) • Third-party impact assessments	Many TVET colleges participate in funded initiatives that include DT goals.
5.	**Internal audit reports on digital resource utilisation** **Risk management or change management frameworks**	These shed light on administrative decision-making and resource allocation.

5.11 Measures of trustworthiness

In the twenty-first century, the landscape of research opportunities, approaches, and environments is in a perpetual state of flux, a dynamic condition that also influences associated ethical issues (Ahmed, 2024). To uphold the rigour and credibility of the present study in such a changing environment, meticulous care was taken to ensure that the research processes for data collection and interpretation met the requirements of trustworthiness and validity.

A key aspect of this was the intentional design of the data collection instruments. To ensure a thorough and systematic exploration of the research questions, the interview questions were tailored to each participant's specific role and level of responsibility. For example, the questions posed to Campus managers differed from those asked of MIS managers, and likewise, the questions for lecturers were distinct from those for ICT managers. This approach ensured that the questions were relevant to the participants' expertise and experiences, thus enhancing the validity of their responses.

Furthermore, participants were consistently encouraged to provide comprehensive responses, a practice that furnished the present study with a rich and extensive dataset for analysis. To guard against misinterpretation, clarification was sought from participants as needed during the interviews, a proactive measure to ensure that the nuanced meaning of their responses was accurately captured for the subsequent analysis and presentation of findings.

5.11.1 Methodological rigour

The present study adopted an interpretive qualitative approach, integrating semi-structured interviews with focus group discussions to gain in-depth insights into the challenges and opportunities surrounding SDT in South African TVET colleges. The method enabled a holistic and context-sensitive understanding of institutional support systems, educator beliefs, and levels of digital competence (Joseph et al., 2024). The use of semi-structured interviews ensured methodological rigour through rich, detailed narratives that enhanced the credibility and trustworthiness of the findings. At the same time, focus group discussions enabled collaborative reflection and triangulation of findings across multiple participant groups.

Through exploring key gaps in digital readiness, educator proficiency, and infrastructure, the present study contributes to both policy and practice aimed at improving equitable access, CPD, and institutional innovation (Montenegro-Rueda and Fernández-Cerero, 2023; Chen and Chan, 2024). In addition to advancing scholarly discourse, the study provides practical recommendations for TVET colleges seeking to implement sustainable and contextually appropriate DT strategies. It also offers empirical insights into educators' digital training experiences, including those working in special education contexts.

The present study was designed to empower stakeholders with actionable knowledge to drive effective, scalable digital initiatives, thereby enhancing the overall quality of teaching, learning, and governance within the TVET sector (Zeehan, Alias and Tasir, 2020). Through the development of context-specific strategies grounded in interview-based findings, the study aims to strengthen teaching and learning environments, foster students' skill development, and contribute to a more competitive national workforce. As digital competence becomes increasingly vital in higher

education, the present study addresses the need to better integrate digital technologies into pedagogical practice and to improve educator preparedness for leading sustainable digital change (Zeehan et al., 2020; Srivastava and Dangwal, 2021).

5.11.2 Ensuring reliability and trustworthiness

In qualitative research, the concept of reliability is not defined by the rigid standards of replicability found in quantitative paradigms. Rather, it is conceptualised as methodological consistency; that is, the extent to which a study's design, execution, and interpretation consistently reflect the lived realities of participants (Leung, 2015; Dhobi, 2023) In the present study, consistency was maintained by ensuring that all participants were asked a standardised set of core questions aligned with the research objectives. The approach ensured comparability across datasets, particularly concerning how leadership, governance, policy implementation, digital pedagogy, infrastructure, and student outcomes influence SDT strategies in South African TVET colleges.

Each research question informed specific components of the data collection instruments. The present study applied uniform interview protocols and posed the same core questions to all participants, while providing equitable opportunities for them to articulate their perspectives (Ahmed, 2024). This approach ensured comparable and coherent data across the diverse TVET institutional contexts, directly supporting sub-questions 1 and 2, which investigate the integration of digital tools into curriculum delivery and the extent of technology use by educators and students. Research sub-questions 1 (on institutional and technical enablers or barriers, and curriculum delivery and pedagogy) shaped the interview protocols for Post-levels 2 and 3 lecturers. Research sub-questions 2 and 3 (relating to the extent of technology utilisation and the role of leadership and governance) were addressed through targeted probes to MIS, ICT, and Campus managers. Lastly, Research Question 4 (focused on policy alignment) was explored across stakeholder groups through cross-cutting themes and follow-up questions. The alignment enhanced the internal consistency and ensured that each response could be meaningfully compared and triangulated within its thematic domain.

Trustworthiness in qualitative research goes beyond reliability and is foundational for establishing the credibility, authenticity, and analytical depth of findings (Noble and Smith, 2025). The present study adhered to the four interrelated criteria of trustworthiness: credibility, transferability, dependability, and confirmability (Korstjens and Moser, 2018; Ahmed, 2024; Noble and Smith, 2025).

Credibility was achieved through prolonged engagement with participants and triangulation of data sources, including semi-structured interviews, focus groups, and document analysis (Mtshali et al., 2020). These practices helped capture multiple perspectives and enrich the understanding of the

complex institutional, pedagogical, and governance dynamics underlying DT, thereby addressing sub-questions 1 and 3.

Member checking involved presenting preliminary themes back to participants to validate interpretations, especially around issues of resource constraints, institutional culture, or pedagogical shifts (Joseph et al., 2024). Peer debriefing and reflexivity practices further strengthened the confirmability of results by mitigating researcher bias and encouraging transparency throughout the analytic process (Noble and Smith, 2025). These strategies were especially relevant in analysing the role of leadership and governance in driving DT (sub-question 3).

Triangulation through semi-structured interviews, focus groups, and document analysis directly supported the study's purpose by exploring SDT strategies from multiple institutional and professional perspectives. These methods were mapped to specific research questions to ensure comprehensive coverage and saturation. For example, focus groups with lecturers enriched the findings related to pedagogy and student engagement (Research sub-questions 1 and 2). At the same time, policy documents and strategic plans illuminated governance issues (Research sub-questions 3 and 4). To facilitate the dependability and confirmability of findings, particularly relevant to sub-question 4, which calls for policy recommendations, a detailed audit trail was maintained. This included clear documentation of research decisions related to data collection, coding procedures, theme development, and interpretation (Stenfors et al., 2020).

Dependability was ensured through an audit trail documenting the entire research process, from instrument design to final coding. This transparency supports future replication or comparative studies, even within qualitative epistemologies. Confirmability was enhanced through reflexive journaling and peer debriefing. The present study regularly documented personal assumptions, especially around digital inequality and policy efficacy, and sought feedback from colleagues to critically assess the analytical process (Noble and Smith, 2025). Transferability was addressed by providing rich, thick descriptions of institutional contexts and practices, enabling readers to determine the applicability of findings in other educational settings.

Philosophically, the present study draws from a relativist ontology and subjectivist epistemology, acknowledging that reality is socially constructed and that the researcher plays an active role in interpretive engagement (Dhobi, 2023). This stance needed the present study to remain reflexive and transparent about values, assumptions, and possible biases throughout the study (Miles et al., 2019). Such axiological awareness was essential when interpreting data from different stakeholder groups with varied experiences and power relations within the TVET ecosystem. Axiologically, the study

acknowledges the researcher's values and positionality, affirming the interpretive and value-laden nature of qualitative inquiry.

In summary, the rigorous application of trustworthiness principles ensured that findings are not only credible and dependable but also meaningfully aligned with the research questions and the conceptual research framework. In maintaining methodological consistency, practising reflexivity, and grounding the study in a robust interpretivist paradigm, this study presents a trustworthy and contextually rich account of SDT strategies in South African TVET colleges.

5.11.3 Mitigation of bias

Bias in qualitative research refers to systematic distortions or partialities that can influence the research process, data collection, analysis, and interpretation, potentially compromising the credibility and validity of findings. Unlike quantitative research, which often relies on standardisation and statistical controls to mitigate bias. Qualitative inquiry involves active researcher engagement and interpretation, making it particularly susceptible to various forms of prejudice or vulnerable to subjective influence (Creswell and Creswell, 2018; Noble and Smith, 2025).

Given these challenges, deliberate strategies were required to identify, reduce, and manage bias throughout the research process. Researcher bias, where the researcher's personal beliefs, values, assumptions, or expectations inadvertently shape data collection, participant responses, or thematic interpretation (Johnson, Adkins and Chauvin, 2020). Another is selection bias, involving non-representative sampling or privileging certain participant perspectives over others (Maxwell, 2013). Response bias refers to the situation where participants provide socially desirable answers or withhold information due to the interview context or perceived consequences (Rubin and Rubin, 2012). An example is when participants are motivated to present themselves or their institutions in a positive light, leading them to exaggerate successes or minimise challenges related to DT initiatives. Alternatively, participants might withhold negative feedback out of concern for possible repercussions or to align with what they believe are the researcher's expectations. Lastly, confirmation bias occurs when researchers focus on data that supports preconceived ideas while neglecting contradictory evidence (Sandelowski, 2010). Such biases often affect the authenticity, accuracy, and depth of the collected data, signifying the importance of employing strategies such as reflexivity, triangulation, and assurances of confidentiality to mitigate their impact.

To proactively address these challenges and enhance the trustworthiness of the present study, a deliberate, multifaceted strategy was employed to identify, reduce, and manage potential bias throughout the research process. A cornerstone of this approach was reflexivity. First, the researcher's reflexivity was an integral part of the research design. Throughout the research process, the present

study engaged in continuous self-reflection regarding personal beliefs, assumptions, and evolving expectations. Reflexive journaling was employed to document these reflections, enabling transparency in decision-making and awareness of how the 'worldview of the present study might shape the study (Finlay, 2014). This practice enabled the present study to consciously separate its own perspectives from the data, ensuring transparency and promoting a more objective interpretation of the findings.

Furthermore, the study leveraged several established methodological techniques to counteract bias. Triangulation was a key strategy, involving cross-verification of findings across multiple data sources and collection methods, namely semi-structured interviews, focus group discussions, and document analysis. In comparing and contrasting insights from these collection methods, the present study built a more robust, holistic understanding. This methodological triangulation enhanced the richness and depth of the data and allowed for cross-verification of themes, thus reducing dependence on a single perspective or method (Denzin and Lincoln, 2018).

To minimise interviewer bias, standardised data collection protocols were implemented. Standardisation of data collection procedures also contributed to reducing potential bias. All study participants across various groups were asked a consistent set of questions during interviews and focus groups, ensuring a fair and equitable platform for expressing their views and experiences. This consistency minimised the influence of interviewer bias and allowed for meaningful comparisons across stakeholder groups (Guest et al., 2020).

In addition, member checking was employed as a means of validation. Member checking is a process where preliminary interpretations and thematic summaries are shared with participants to verify their accuracy and authenticity. This iterative process was a key step that allowed study participants to clarify misinterpretations and correct misunderstandings. It ensured that their views were authentically represented, strengthening the authenticity of the data (Birt, Scott, Cavers, Campbell and Walter, 2016).

To ensure transparency to support rigour, a comprehensive audit trail was maintained throughout the present study. This included detailed records of all research decisions, from data collection procedures and coding decisions to the development of analytic memos. The audit trail provides a verifiable path that others can follow, reinforcing the dependability of the research process and findings (Denzin and Lincoln, 2018).

Finally, regular peer debriefing was integrated into the study through regular engagement with academic supervisors and colleagues. These interactions offered foundational feedback and

alternative interpretations, helping to challenge potential blind spots and to minimise the influence of individual bias from shaping the conclusions (Shenton, 2004).

Diligent implementation of these strategies created a systematic and reflexive approach to mitigating the inherent risks of bias in this qualitative research. While a degree of subjectivity is inevitable, these strategies ensured that the findings faithfully represent participants' experiences and the complex realities of SDT strategies in South African TVET colleges, thereby enhancing the overall credibility and validity of the research outcomes.

5.12 Ethical considerations

Before commencing the research, the present study applied for ethical clearance from the University of South Africa (UNISA) Ethics Committee by detailing the nature and scope of the study. Ethical clearance was obtained from the relevant institutional review board. Upon review, the application was approved, and the UNISA Ethical Clearance Certificate (Appendix A) was duly issued, authorising the present study to proceed. Informed consent was secured from all participants, and confidentiality was maintained through pseudonymisation and secure data handling. Study participants were informed of their right to withdraw without consequence. That is, participants were clearly informed of their right to withdraw from the study at any time without any negative consequences.

5.12.1 Informed consent

Informed consent serves as a cornerstone of ethical research, ensuring that individuals participate willingly in studies with a clear understanding of the potential implications and their rights. This foundational principle respects autonomy and safeguards participants from exploitation or harm, recognising their right to determine whether research participation aligns with their interests (Grady Cummings, Rowbotham, McConnell, Ashley and Kang, 2017; Tiruneh, Yilma, Wakuma, Abdisa, Bayisa and Nichols, 2024). Informed consent is more than a mere formality; it is a process where a potential participant makes a knowledgeable decision to engage in a study, clinical trial, or practice after a thorough explanation of the procedures, possible risks, and anticipated benefits (Bhupathi and Ravi, 2017; Kandi and Vadakedath, 2022). The practice of obtaining informed consent arose from a need to prevent exploitation and unethical practices in the life sciences, solidifying its importance in protecting participants' rights (Bhupathi and Ravi, 2017). Guidelines on informed consent are foundational for ethical research conduct, focusing on the protection of participants.

The core of informed consent comprises three indispensable elements: voluntarism, comprehensive disclosure of information, and decision-making capacity (Gupta, 2013). Voluntarism ensures that

participation is free from coercion or undue influence, allowing individuals to make choices without external pressure (Tiruneh et al., 2024). Information disclosure entails researchers providing detailed information about the study's purpose, procedures, potential risks, benefits, and alternatives, allowing participants to make informed decisions (Kandi and Vadakedath, 2022). Decision-making capacity necessitates that participants possess the cognitive ability to comprehend the information presented and appreciate the potential consequences of their choices (Kadam, 2017). This multifaceted approach guarantees that individuals are genuinely aware of what their involvement entails. The present study ensured that each element was met to guarantee ethical research practices.

Respect for participants, beneficence, and justice create the ethical framework of any research concerning human subjects (Tiruneh et al., 2024). Respect for individuals highlights the right of a person to make their own decisions, and requires that researchers respect the autonomy, privacy, and well-being of participants (Kandi and Vadakedath, 2022). Beneficence emphasises the need to maximise benefits and minimise risks associated with the research. Justice demands equitable participant selection, ensuring no group bears a disproportionate share of research risks while guaranteeing equal access to its potential benefits. These principles emphasise the imperative need for informed consent in protecting participants' rights and welfare, ensuring that they are treated with dignity and respect throughout the research process (Gupta, 2013; Dankar, Gergely and Dankar, 2019; Kandi and Vadakedath, 2022). Informed consent enabled the individual to make an autonomous, informed decision about participation (Jansen, 2018).

The complexity of informed consent is ever-increasing, with a multitude of international rules and ethical guidelines governing its various aspects in ICT research. This complexity arises from the dynamic nature of research, particularly with the emergence of Big Data and vast data warehouses, making it challenging to foresee all potential uses of participant data (Dankar et al., 2019). The informed consent process was robust enough to adapt to these complexities and flexible enough to accommodate the diversity of research settings and participant populations (Gupta, 2013). The procedures for obtaining informed consent were flexible, but not at the expense of its primary purpose.

For the present study, each participant was provided with an informed consent form before the interview could start (Appendix C). Study participants were required to sign the form as evidence that they were fully informed about the nature, scope, and objectives of the study, what was expected of them, and how they may benefit professionally from the study findings.

5.12.2 Confidentiality

Confidentiality remains a fundamental principle in research, widely acknowledged as essential to maintaining the trust and integrity of the study. Confidentiality entails researchers' commitment not to disclose, explicitly or implicitly, any information provided by participants to unauthorised third parties (Kandi and Vadakedath, 2022; Tiruneh et al., 2024). This understanding aligns closely with the principles outlined in the Protection of Personal Information Act (POPIA) No. 4 of 2013 (Government Gazette, 2013). The Protection of Personal Information Act (POPIA) No. 4 of 2013, WHICH emphasises the necessity of safeguarding personal information and mandating that researchers implement appropriate technical and organisational measures to prevent its loss, damage, or unauthorised use. Furthermore, researchers are obliged to actively prevent unlawful access and processing of such information (Government Gazette, 2013). In the present study, safeguarding privacy and confidentiality was prioritised beyond statutory requirements. The digital voice recorder used during interviews was securely stored under lock and key with the lead researcher, ensuring restricted access. Transcriptions derived from these interviews were similarly protected once completed. After each phase of data analysis, all transcripts were promptly secured. At no point were the voice recordings or transcribed documents accessible to individuals outside the research team.

5.12.3 Protection from harm

Protecting participants from any potential harm that may arise from their involvement in research is a fundamental ethical obligation for researchers. As emphasised by Dhobi (2023), researchers must take proactive steps to minimise risks, including safeguarding personal information through various strategies. These include secure data storage, the removal or alteration of identifying details, and the use of pseudonyms to maintain confidentiality. Similarly, Saunders et al. (2023) highlight that such measures are key for preserving participant anonymity and preventing any adverse consequences associated with their participation.

In the present study, these protective measures were applied to ensure participants were protected from potential harm. Interview transcripts were anonymised by coding to conceal participant identities, and all data were securely stored to maintain confidentiality throughout the research process. There was no foreseeable physical or emotional harm endured.

5.13 Research procedure overview

The present study followed a systematic and sequential research process to ensure methodological rigour, transparency, and alignment with the study objectives. The following steps outline the research procedure followed in conducting the study:

1. **Selection of participating colleges:** Based on S4GJ or DHET involvement
2. **Ethical approval and participant recruitment**
3. **Data collection:** Semi-structured interviews, FGDs, document analysis
4. **Data management:** Transcription, coding, anonymisation
5. **Data analysis:** Open, axial, and selective coding, and thematic development using ATLAS.ti 25 Windows software
6. **Validation:** Triangulation and member checking

This structured yet flexible research design ensures methodological coherence and alignment between philosophical stance, research objectives, data collection, and analysis. The study outcomes may inform policy and practice in sustainable and inclusive DT within South Africa's TVET sector.

5.14 Chapter summary

This chapter outlined the comprehensive strategies and procedures employed to achieve the research objectives, aligning each methodological step with the research questions. It provided clarity by integrating both the philosophical foundations and justifying the chosen methodology. The chosen methods and techniques align with the research purpose and goals, advancing theories of participants' lived experiences of SDT in South African TVET colleges.

The chapter articulated the philosophical coherence of the methodology within ontology, epistemology, and axiology. Qualitative data collection involved semi-structured interviews and focus group discussions with fifteen institutional leaders, including both academic and non-academic staff from five public institutions. Additionally, document analysis of DHET policy frameworks, SDT project reports, and institutional ICT strategies was conducted. This triangulation of data sources enhanced the robustness of findings by comparing policy intentions with actual institutional practices.

Participants were purposively selected using stratified purposive sampling to ensure representation across key stakeholder groups: MIS, ICT, and Campus managers, with Post-levels 2 and 3 Lecturers. Data management protocols emphasised confidentiality and secure handling, with interviews audio-recorded and transcribed verbatim. The data analysis followed an iterative thematic approach embedded within grounded theory coding, comprising open, axial, and selective coding phases. This was facilitated by ATLAS.ti 25 Windows software to maintain coding consistency.

The chapter also reflected the methodological choices and epistemological assumptions, affirming that qualitative research was best suited to address the research problem. Concepts integral to qualitative inquiry, such as trustworthiness, ethical considerations, and sampling techniques, were

thoroughly described. Triangulation of multiple data sources was detailed, illustrating how themes, categories, and subcategories were developed through a systematic analysis.

Importantly, the chapter highlighted the attention given to addressing bias in qualitative research. It discussed the various types of biases that can affect qualitative studies, their potential implications for data integrity, and the strategies employed to identify, minimise, or control these biases throughout the present study, thereby reinforcing the methodological integrity and credibility of the findings.

Building on this rigorous foundation, the next chapter analyses data and discusses the study findings, offering insights into how SDT strategies are executed within South African TVET colleges and their impacts on teaching, learning, research, and governance.

Chapter Six: Data Analysis and Discussion of Findings

The previous chapter, Chapter Five, described the research methodology used to conduct this study. In this chapter, the data are analysed, and the study findings are discussed by study themes. Themes are synonymous with study objectives.

The chapter is structured as follows: Section 6.1 briefly states the chapter's purpose, presenting and interpreting the findings in line with the research questions and the theoretical framework. Furthermore, it discusses how themes were developed through inductive thematic analysis, grounded in open, axial, and selective coding. Section 6.2 is organised into five parts, each addressing key findings related to themes that emerged. Section 6.3 summarises the key insights, particularly how the findings relate to themes. Furthermore, the section discusses the implications for policy, leadership and equity. Section 6.4 follows with a summary of Chapter Six.

6.1.1 Individual interviews

The individual semi-structured interviews (Appendix D1-D3) were conducted online via Microsoft Teams, with all but one participant stating they were not at their respective college due to Internet challenges. The individual semi-structured interviews were conducted with MIS managers to gain insight into governance, data, and analytics, while ICT managers provided insights into technical depth and infrastructure. Campus managers gave administrative insights and leadership vision. In addition, multiple documents were analysed for their relevance to the topic under investigation. The use of various data sources in qualitative research goes beyond reliability and is foundational for establishing the credibility, authenticity, and analytical depth of findings (Noble and Smith, 2025).

6.1.2 Post-levels 2 and 3 lecturers' focus group interview

The specialised individual interviews were supplemented by two focus group interviews (Appendix D4) with Post-level 2 and 3 lecturers (Senior educators) participating. The two focus groups each consisted of three participants. The collection of this data was to gain insight into the perspectives of TVET officials on the factors that facilitate or impede the integration of digital tools into curriculum delivery and pedagogical practices. The Post-level 2 and 3 Lecturers (Senior Educators) are frontline implementers of digital tools in teaching and learning, and they effectively addressed topics related to student engagement and pedagogical shifts. Table 6.1 presents a breakdown of the participants' demographics, including the codes used for identification, gender, and years of relevant experience in the TVET sector in South Africa.

Table 6.1: The included multiple roles and demographics

PARTICIPANT	CODE	GENDER	YEARS OF EXPERIENCE
Participant 1	MIS1E	**Male**	**9**
Participant 2	MIS2A	**Male**	**18**
Participant 3	MIS3B	**Male**	**11**
Participant 4	ICT1D	**Male**	**14**
Participant 5	ICT2C	**Male**	**7**
Participant 6	ICT3A	**Male**	**18**
Participant 7	CM1B	**Male**	**15**
Participant 8	CM2D	**Male**	**22**
Participant 9	CM3A	**Female**	**17**
Focus group 1			
Participant 10	F1P1A	**Male**	**13**
Participant 11	F1P2A	**Female**	**21**
Participant 12	F1P3C	**Male**	**25**

Focus group 2			
Participant 13	F2P1B	**Male**	**21**
Participant 14	F2P2B	**Female**	**23**
Participant 15	F2P3D	**Female**	**10**

6.1.3 Reflection on Sample Realisation

Although the initial sampling framework proposed a larger participant pool, the target sample size was 42-56 lecturers, 6-8 focus groups, and 7-15 managers (Table 5.2). Practical access constraints and participant availability influenced the final sample achieved. The actual sample consisted of 9 individual interviews and 2 focus groups with 6 participants each, for a total of 15 participants (Table 6.1).

However, within qualitative methodologies, sample size is not determined by statistical representativeness but by achieving theoretical saturation (Charmaz, 2014; Saunders et al., 2023). Despite the reduced numbers, the participants represented all key stakeholder categories relevant to SDT in the participating TVET colleges.

6.2 Organising the study findings

The themes in Table 5.4 serve as the main headings and subheadings for the discussions in this chapter. In the discussion of the findings, verbatim accounts have been selected to offer information regarding participants' own perspectives and interpretations of the research topic. It is worth noting that experience and meaning are significant concepts in achieving research objectives targeted at qualitative understanding (Qolamani and Mohammed, 2023; Sibiya, 2024). Thematic clusters are organised and aligned with the conceptual research framework. Table 6.2 demonstrates the flow from Themes to Categories to Sub-categories.

Table 6.2: Themes to Categories to Sub-categories

	Main Theme	**Category**	**Sub-Categories**
1.	**1: Strategic Vision and Leadership**	Strategic Planning	• Long-term vision and planning • Digital maturity models • Alignment with national digital

	Main Theme	Category	Sub-Categories
			skills agendas
		Leadership and Vision	• Role of leadership in SDT • Executive support • Distributed leadership
2.	**2: Institutional Capacity**	Infrastructure & Resources	• Infrastructure gaps • System integration challenges
		Human Capacity	• Staff digital literacy • Staff competencies
		Professional Development	• Continuous professional development • Technical support systems
		Digitisation of Administration	• Online registration • Digital record-keeping • Assessment technologies
		Institutional Integration	• Collaboration between ICT, Academic, and MIS units • Communication gaps
3.	**3: Change Management**	Organisational Culture	• Resistance to change • Communication and stakeholder involvement
4.	**4: Digital teaching and learning**	Teaching Practice Transformation	• Digital tool integration • LMS usage • Hybrid or blended models • OER
		Student Engagement	• Student access

	Main Theme	Category	Sub-Categories
			• Technology-mediated learning
5.	**5: Financial and Equity Considerations**	Access & Equity	• Connectivity issues • Rural vs urban disparities • Student access to devices
		Policy Gaps & Implementation	• Policy implementation gaps • Monitoring and evaluation • Alignment with DHET frameworks
		Equity-Driven Planning	• Bridging the digital divide • Under-resourced campus support
		Policy Formulation	• Stakeholder-informed strategies • Scalable DT frameworks

6.2.1 Theme 1: Strategic vision and leadership

The first theme captures the extent to which leaders in TVET colleges show strategic foresight, promote DT, and align campus initiatives with the national skills agendas. Furthermore, the analysis of this theme demonstrates variation in leadership conduct across the TVET colleges. Although colleges A, B, and C reveal a vision grounded in SDT principles, colleges D and E articulate strategies that are fragmented and lacking measurable implementation paths.

6.2.1.1 Category 1: Strategic planning

Participants articulated inconsistent visions and plans for the long term. In certain instances, the long-term DT plan exists only on college documents, yet it lacks operationality. Participants characterise long-term planning as reactive rather than anticipatory. Evaluation of digital maturity models is either inconsistently applied or almost non-existent. Participants highlighted that their respective colleges envisioned alignment with national digital skills agendas. Evidence suggests that current strategies are more focused on acquisitions than on sustainable integration.

The evidence suggests that DT's strategic planning is aspirational rather than operational. While some TVET institutions highlight five-year roadmaps, such plans lack measurable milestones and budget alignment. Under the Strategic Planning category, ICT2C explained: *We devised what we call an ICT strategy in line with our strategic plan of the institution… We also devised a roadmap to see how best we can sustain it.* Contrastingly, MIS managers acknowledge that due to resource constraints, implementation remains slow. MIS1E, noted: *We are decades away from that day… We're getting there, but we are still very far.*

One campus manager explained how College D is trying to adapt to 4IR: *We need to move into the 4IR… We are trying as far as possible to look at digital teaching and learning by introducing open learning and blended learning* (CM2D). Such initiatives indicate that planning documents do exist, yet translating these plans into actionable steps remains a stumbling block and is inconsistent, reflecting a gap between execution and vision.

Across the five TVET college cases, strategic planning of DT is indicated as more aspirational rather executable. These colleges often possess high-level plans and over five-year ambitions, yet these documents do not reliably translate into sequenced milestones, budgets, or risk-managed delivery. Colleges A and B demonstrate instances where planning is reported as moving beyond rhetoric; there is phasing and governance tied to the Annual Performance Plan (APP). However, in Colleges D and E, planning is reactive, oriented around immediate acquisitions and not phased capability building.

Findings suggest three obstacles to strategic planning: the proposed DT roadmaps are not anchored in funding, resulting in inadequate support for digital priorities. The strategic departments of ICT and MIS are often not included from the outset, leading to designs that cannot be executed on legacy infrastructure. ICT1D stated: *Maybe the ICT department was never involved. So then you come, and you want systems to run. But those systems cannot run on the current infrastructure, and if only you had included IT from the planning or implementation phase, problems like that would have been covered.*

The third reported obstacle is the underestimation of risk and capacity, wherein the human and cultural work necessary to shift practice is lacking. These three constraints create a gap in the execution of the institution's vision. That is, they can describe the future they want, yet fail to sequence how to reach their destination.

6.2.1.2 Category 2: Leadership and vision

Leadership engagement has been identified as an important factor in SDT strategies. Institutions in which senior management was viewed as actively involved indicated more coherent digital initiatives.

However, in several instances where executive attention was drawn to compliance issues, these digital initiatives were underprioritised.

Regarding leadership and vision, MIS1E commented: *Moving ICT from a secondary unit to a primary unit… everything is revolving around that particular unit in terms of where we are going.* Manager (ICT2C) emphasised: *Council sometimes goes over and beyond, seeing that we might have short-changed ourselves… They can prioritise certain money to support our initiatives*. In contrast, participant F1P3C highlighted the discrepancies between management expectations and staff's own competencies: *You cannot expect somebody to do something that you cannot do… If you cannot use Moodle, why would you ask staff to use Moodle?* Furthermore, MIS2A stated: *We want to phase out textbooks and bring in e-books, but there are challenges around devices and policies… The vision is there, but implementation is slow.* The preceding statements demonstrate that compliance-driven leadership correlates with low follow-through, inconsistent expectations, and staff scepticism.

The evaluation of the five colleges reveals that colleges A, B, and C present relatively coherent strategic visions aligned with SDT principles and national digital agendas. The three institutions exhibit long-term patterns, such as the phased integration of online platforms and LMS adoption, although with differing degrees of operationalisation. Conversely, colleges D and E reveal fragmented strategies, often reactive than anticipatory, with constrained measurable implementation paths. Leadership engagement emerged as a key differentiator: when senior management actively advocates for digital initiatives (A and B), progress is more structured, whereas passive or compliance-driven leadership (D and E) correlates with slower uptake.

The benefit of leadership engagement is its ability to redirect actions when they drift away from goals. The findings suggest that when senior leaders advocate for DT as a core institutional project, the results are more coherent initiatives. Even committed leaders concede structural constraints, signalling that leadership intent must be matched with distributed decision-rights, budget shifts, and clear accountability.

6.2.2 Theme 2: Institutional capacity

The second theme of Institutional capacity includes infrastructure, human resources, professional development, administrative digitisation, and cross-departmental collaboration. This theme is representative of the operational backbone of SDT strategies. It demonstrates inconsistencies amongst strategic ambitions and the TVET institutions' ability to support DT.

6.2.2.1 Category 1: Infrastructure and resources

The study findings reveal how persistent infrastructure shortcomings undermine the scalability of DT across the TVET colleges. Findings indicate that most campuses operate on outdated LAN systems and legacy hardware, and thus are unable to support modern learning platforms. As the ICT manager from College C commented: *Our computer labs… are still running on old technology, where we find that we're still sitting on Category 5 (CAT5), whereas everybody's on Category 6 (CAT6)* (ICT2C). In concurrence, an F1P3C noted: *We still have overhead projectors in our venues… only in the computer labs… about 10% of our staff use PowerPoint.* Similarly, the campus manager of College D highlighted that *Infrastructure and connectivity are always a challenge… We have five campuses, and our central office is quite a distance away. All services and connectivity are dealt with from a central point* (CM2D). Similarly, ICT1D further articulated: *So, we are now on Windows 11, but we still run machines that can only support Windows 10.* Even when bandwidth improves, device capability and power resilience lag. These plumbing problems (LAN, Wi-Fi density, power, endpoint health) repeatedly cap the ceiling of what pedagogy and administration can do.

These infrastructure gaps highlight systematic under-investment and centralised control, limiting responsiveness to campus-level needs. Even when upgrades occur, they are partial and reactive rather than anticipatory. This staggered approach leaves TVET colleges decades away from full readiness. This pattern reveals that infrastructure failure is not merely technical but rooted in governance and funding priorities.

Findings revealed constraints that impede the scalability of digital teaching and administrative digitalisation. These constraints include limited bandwidth, outdated devices, fragmented digital systems, inconsistent Wi-Fi access, and challenges with integrating LMS platforms.

6.2.2.2 Category 2: Human capacity

In reference to workload pressures, F2P2B indicated access barriers to CPD and reliance on personal resources: *We do get training now… but sometimes it's our Wi-Fi, we don't always have Wi-Fi at work, so you must do it in your own time on your own device.* The academic staff's digital literacy is demonstrated as uneven. MIS and ICT staff often operate under significant workload pressures. The participant MIS1E noted: *Digital literacy among staff… we are not the same, and the change that is coming, we are not all ready for it.* Additionally, support ratios and first-line resolution appear thin, as upskilled ICT staff are enticed to the private sector. ICT2C detailed: *We employ new graduates, we try to upskill them, and once we have upskilled them… they are snapped up by the private sector.* Another manager echoed similar sentiments, linking technical investment to human resource limitations. MIS2A noted: *It doesn't help you put down a state-of-the-art IT system that costs millions*

of rands, but you do not have staff capable or with the knowledge and training to actually use it. The finding is clear for leadership: staff capabilities should not be assumed; rather, they must be designed, resourced, and retained.

6.2.2.3 Category 3: Continuous Professional development

Staff's digital competence varies widely. Participants highlighted variation in digital proficiency among their colleagues, attributing it to age differences. Those nearing retirement are often not interested in using digital tools, regardless of any training efforts provided. Technical support is lacking across campuses. For example, ICT1D expressed: *They talk about robotics and AI, but forget that ICT support staff also need training, so we're all on par.* Such a comment demonstrates that the ICT support department also needs to participate in these training initiatives so it is available to support when problems arise. Such an approach will likely reduce constant calls to suppliers who charge to come out and do something that the ICT support department could have done.

Continuous professional development offerings have been described as focusing on tools and not pedagogical integration. Furthermore, it is described as not regular or generic, but rather context-specific. Lecturers note that training without practice yields little value. F1P3C added that training exists but lacked practical uptake: *but unless you actually try something after being trained… we're not going to go anywhere... We can train you until we are blue in our faces… for as long as you don't switch your computer on and fiddle around… you're not going to get anywhere.* F1P3C reflected on staff reluctance and low digital confidence. Where CPD is structured, iterative, and tied to lesson redesign, uptake is stronger; otherwise, confidence and transfer remain low.

6.2.2.4 Category 4: Digitisation of administration

The digitisation of administrative systems is partial and uneven. Participants reveal an uneven online registration landscape, with colleges C and D still reliant on paper-based systems. For colleges B and E, the online registration system remains unstable or inconsistently implemented. Assessment technologies are viewed as existing but underutilised by many staff. A concerning issue is that digital record-keeping systems are perceived as not interoperable across departments. For example, ICT1D cites: *Yeah, we have a few strategies. We have strategies that are on paper, sitting in the management's offices, detailing what we want to happen. Where we want to be. So, it's now a matter of ensuring that we have the financial resources to implement, because everything will have to be done in stages.* MIS1E clarified: *The idea behind having a business management system is to have one version of the truth… but integration with third-party software remains a challenge.* Colleges with BMS-LMS integrations show fewer errors and less double-capture (ICT2C), but these are exceptions rather than the norm.

6.2.2.5 Category 5: Institutional integration

There is limited collaboration between MIS, ICT, academic departments and campus management. Participants emphasised that this limitation leads to conflicting responsibilities. Moreover, there are conflicting responsibilities, a lack of coordinated planning, duplication of effort across campuses, and limited shared access to institutional data. F2P2B highlighted informal peer-support systems compensating for the lack of structured integration: *We created WhatsApp groups… and we make WhatsApp calls… to share information and support each other.* Where a cross-functional steering mechanism exists, and decisions are data-informed, colleges reduce friction and scale wins faster.

Infrastructure constraints are prevalent across all five participating colleges (A-E); however, their severity levels differ. Colleges A and B reveal partial upgrades, including LMS integration and enhanced bandwidth, whereas Colleges C, D, and E struggle with outdated systems, inconsistent Wi-Fi, and legacy hardware. Human capacity challenges are widespread, as evidenced by uneven digital skills and workload pressures. Continuous professional development efforts are exhibited, yet are often irregular and disconnected from pedagogical integration. Colleges C and D face compounded barriers due to limited connectivity and resource limitations.

6.2.3 Theme 3: Change management

The third theme evaluates how organisational culture influences the integration of digital technologies. The central challenges identified by participants include resistance, communication gaps, as well as divergent campus cultures.

6.2.3.1 Category 1: Organisational culture

Staff resistance to change has emerged as a contributing factor, as indicated by participants' responses. Participants indicated an existing preference for traditional teaching practices. For resistance to change, CM2D noted: *Some staff members still want to use the chalkboard… They say, 'I've got two years to retire, do it when I'm gone.' Others resist initially but gradually come around when shown the benefits.* In indicating resistance to change among senior staff, F1P3C stated: *Our older people are very reluctant and very sceptical of anything digital.*

Resistance is strongest when messages are inconsistent, expectations are misaligned, or staff are near retirement and see limited return on the time spent learning new systems. Conversely, clear communication, visible leadership, and safe-to-try pilots reduce resistance. Staff collaboration efforts vary widely. Participants emphasised a lack of clarity in communicating digital initiatives, opportunities to influence decision-making, and consistency in senior leadership messaging. Where communication was effective, digital uptake was notably high. Under Organisational culture, MIS1E

specified: *resistance to change… some staff are not interested in using digital tools regardless of any training efforts provided.* In addition, MIS1E detailed: *We do try and provide ongoing support… but accountability for data accuracy from different units is still lacking.*

Supporting resistance and reliance on traditional methods, F2P1B stated: *I'm still a textbook man… I hope the QCTO will address all these issues going forward.* Staff shift from scepticism to participation when benefits are concrete (time saved, better results) and support is immediate. When leadership treats DT as iterative and invites participation, cultural barriers soften; when DT is framed as a compliance exercise, employees harden.

A recurring theme across all five colleges is resistance to change, particularly among senior staff nearing retirement and those with established teaching traditions. However, institutions with clear communication strategies and visible leadership support (A and B) exhibit higher levels of digital adoption. Conversely, Colleges D and E revealed pronounced resistance, intensified by communications barriers and the lack of structured stakeholder involvement. Findings suggest that culture predicts adoption and not tools. Change management requires transparent communication, distributed ownership, micro-pilots with coaching, and recognition of effort. Without these, technology investments under-deliver.

6.2.4 Theme 4: Digital teaching and learning

Digital teaching and learning encompasses how digital tools are employed in teaching, learning, and assessments across institutions.

6.2.4.1 Category 1:Teaching practice transformation

Participants highlighted the varying practices of integrating Hybrid or blended models, LMS software, and OERs. In instances where integration occurred, participants reported that lecturers who innovated made effective use of multimedia resources, while others used the LMS solely to upload subject notes. In references to the unstructured and selective adoption of digital tools for efficiency, F2P2B expressed: *We make a lot of use of digital projectors… and I'm a big fan of ChatGPT… it makes our work so much easier to quickly set up a class test.* In such cases, student engagement and outcomes improve, even during disruptions. As an example of innovative practices and positive impact, F1P3C stated: *One lecturer in finance… downloaded a free app… recorded herself going through question papers… and the results for that level improved even during strikes.* Participant CM2D concurred: *One lecturer uses PowerPoint linked to Google and YouTube… She even adds pop-up Emojis to keep students engaged during long class sessions.*

The prevailing pattern is selective use of LMS (mostly file repositories), with minimal redesign toward blended, active learning. ICT2C stated: *We've developed our own LMS platform internally to support online teaching and learning… and revision for students.* Correspondingly, CM1B expressed: *We have implemented the new LMS system with Black Ubuntu and other new tools… There was a lot of training and meetings to encourage people to use technology in their classrooms.* Colleges with LMS, coaching, and peer sharing see a shift from content posting to learning design, while others stay at the "upload notes" stage.

6.2.4.2 Category 2: Student engagement

Many students face challenges with device access and data costs. It was reported that engagement improved when lecturers used interactive tools. However, Students' social-media fluency doesn't automatically translate into academic engagement, especially without access. F2P2B highlighted this contrast between social media fluency and academic digital engagement: *If you want to ask them to make a video for TikTok, it's 5 seconds, and they can do it… but still no Wi-Fi on campus, and resources are limited.* This further highlights how digital integration boosted student engagement, F1P3C stated: *Students would skip other classes… even if her class is at the end of the day… they would come because it's interesting, it's relevant, it's not chalk and talk.*

In highlighting socio-economic barriers to student participation, MIS2A stated: *We're working with the poorest of the poor… providing them with a device is a bit of a challenge.* At the campus level, infrastructure inconsistencies negatively affect student participation.

Colleges A and B are focused on innovative teaching practices that leverage multimedia, blended models, and LMS tools. In Colleges A and B, lecturers are reported to be experimenting with interactive content and digital assessments. Conversely, Colleges D and E rely on conventional methods, with minimal LMS use and sporadic integration of digital tools.

Engagement gains are fragile when devices, data, and campus Wi-Fi are unreliable. Student engagement is enhanced when lecturers use creative digital strategies, underlining the potential of technological pedagogy when implemented effectively. Pedagogical transformation emerges where infrastructure works, CPD is coaching-based, and student access is addressed.

6.2.5 Theme 5: Financial and equity considerations

Theme five markedly shapes the capacity of SDT strategies through equity, access, policy alignment, and funding gaps. Findings reveal how financial limitations and structural inequalities constrain digital progress.

6.2.5.1 Category 1: Access and equity

Recurring patterns of equity barriers include urban and rural disparities, student challenges to accessing data or devices, and limitations of campus connectivity. These barriers result in differential digital experiences across student groups and campuses. For instance, regarding the digital divide and equity challenges, F1P3C mentioned: *Devices of students are non-existent… about 90% have smartphones… while 10% cannot afford any device.* To demonstrate financial vulnerability and reliance on state funding, MIS2A stated: *We are dependent on the government to fund everything… if they decide to cut the budget, we basically have to comply.* F2P2B pointed to connectivity and system usability as equity issues: *Reliable Internet to start with, please… and a working LMS that is suitable for the students and us.* Without equity-first planning (zero-rating, device libraries, assistive tech, on-campus coverage), DT excludes the very students it aims to serve.

6.2.5.2 Category 2: Policy gaps and implementation

Participants reported varying levels of access to policy documentation and stated that institutional policy was incomplete or outdated. Many viewed their institutional policy as not aligned with DHET frameworks, citing slow operationalisation at the campus level. Indicating the absence of long-term sustainability planning, ICT3A articulated: *There's nothing… unfortunately, no strategic plan to future-proof IT systems.* CM2D noted: *We don't have any policies for digital transformation… Registration is still paper-heavy despite online applications. There should be policies for paperless registration and digital exams.*

A campus manager stated: *There is a framework on digital transformation from the Department… Policies are clearly defined and communicated, but challenges include infrastructure, digital literacy, and financial constraints (*CM1B). In instances where frameworks do exist, campus-level enactment lags (e-Assessment rules, device custody, cybersecurity, e-Waste). To avoid the proliferation of ad hoc practices, governance structures with external experts must be in place, so that alignment strengthens and decisions improve (ICT2C). In its absence, ad hoc practices proliferate.

6.2.5.3 Category 3: Equity-Driven Planning

Institutions prioritise bridging the digital divide; however, these efforts often face the uncertainty of long-term financial backing. Some leaders negotiate zero-rating and explore tablet provisioning. ICT2C commented: *Our college is predominantly constituted of students from previously disadvantaged backgrounds… When they leave the campuses, they don't have access to data or digital platforms.* ICT2C also noted: *We are in negotiations with service providers to zero-rate our LMS platform and provide tablets equipped with textbooks.*

Another point of view was raised by ICT3A: For semi-rural and rural colleges, funding-wise *is exactly the same. So the department pays the same amount of money to a student.* Evidence suggests that a single funding formula across urban and semi-rural contexts leaves structurally disadvantaged colleges behind, entrenching the digital divide.

6.2.5.4 Category 4: Policy formulation

This category focuses on stakeholder-informed strategies and scalable frameworks for DT. Moreover, a concern is how policies are developed and aligned with the DT for national frameworks, and how they are informed by stakeholder input. CM2D commented: *OK, this one, yeah, I'm going to say no comment because we don't have any policies. Seriously, we cannot be dishonest with you.* Moreover, CM2D clarified that the challenge we face is *financial constraints. If you do have an e-book, that means there must be an electronic device. The challenge with electronic devices is that a policy needs to be established around them. Who does a device belong to? If the device is stolen, what transpires?*

Stakeholder-informed and scalable policies are rare; yet where they do exist, visibility and accessibility matter. Conversely to other participants, particularly campus managers, participant CM1B commented: *Basically, there is a framework for digitalisation, and so on… The policies we actually have are derived from that framework. Our IT department has its own policies on all IT-related issues as well as digitalisation… These policies are typically communicated through meetings and are also available on our website and internal portal, allowing lecturers and all staff to access them.* In further contrast to other participants, ICT2C: *We've put governance structures in place… there's an ICT steering committee chaired by external experts… one from a University, the other one is a CEO of a Digital Innovation Hub… Those mechanisms help us align decisions with our strategic plan.*

Digital transformation is shaped by budget limitations and structural inequalities across institutions. Although each college faces budgetary constraints, rural and semi-rural colleges (C and D) face deeper equity barriers, including connectivity challenges and limited access to devices. Proactive measures are revealed by Colleges A and B, instances include negotiating zero-rated LMS platforms and exploring device provisions, whereas others lack sustainable equity-driven planning. Policy gaps further compound these disparities, with several institutions operating without comprehensive DT policies or alignment with DHET frameworks.

Financial constraints, uniform funding models, and policy vacuums compound exclusion. Sustainable DT requires targeted resourcing (rural weighting), zero-rating and device strategies, and operational policies anchored to DHET frameworks.

6.3 Key Insights and Discussion of Findings

This section explicitly draws implications and outlines the necessary interventions regarding policy, leadership, and equity, serving as the foundation for the policy recommendations. When considered together, the five themes demonstrate that SDT in TVET colleges is not solely a technological project, but a systemic transformation process that requires integrated leadership, capacity-building, cultural change, and equity-focused planning. The themes and categories demonstrate that SDT within South African TVET colleges is shaped by interdependent dimensions of leadership, capacity, culture, pedagogy, and equity. These findings collectively illustrate a complex landscape in which the evaluation of successful SDT strategies relies on a cohesive approach that addresses policy, practice and equity.

6.3.1 Policy and strategy

The colleges currently operating with fragmented strategies, particularly those lacking a coherent vision or measurable implementation paths, need urgent intervention. The DHET must spearhead the development of clear operational frameworks derived from the national strategy. These frameworks are necessary to help colleges translate paper strategies into sustained, real-world integration, moving beyond mere short-term acquisitions.

6.3.2 Leadership and practice

For SDT strategies to succeed, leadership practice must evolve. Leadership development programs should be refocused to emphasise the cultivation of distributed decision-making. Currently, strategic planning suffers from the absence of distributed leadership structures, with limited involvement from instructional leaders and academic heads. In enhancing senior management's digital competency, colleges can shift ICT from a secondary to a primary unit, ensuring that management expectations align with staff capabilities and promoting a more coherent, well-budgeted initiative.

6.3.3 Equity and resource allocation

Finally, achieving SDT strategies demands a commitment to equity-driven planning. Resource allocation must be strategically prioritised for colleges that currently exhibit absent or diminished strategic vision, such as Colleges D and E. Semi-rural and rural colleges often receive the same funding as their urban counterparts, despite differing infrastructural challenges. A targeted funding model is needed to prevent the digital divide from worsening. Without the needed financial support and strategy enablement, the structural inequalities that constrain digital progress, such as inadequate infrastructure and device access barriers, will continue to impede progress from the most vulnerable institutions.

6.4 Chapter summary

This Chapter Six transitions from the methodological descriptions in Chapter Five to the substantive discussion of the study findings. The present study is anchored in the interpretivist tradition, with an emphasis on understanding the subjective reality, experiences, and meanings held by the study participants. The chapter effectively achieves its primary focus of systematically discussing the study themes derived from data analysis, supported by empirical evidence.

This chapter discussed the findings in line with the research questions and the conceptual research framework. Varied themes emerged following the analysis of data from semi-structured interviews, focus groups, and documents. The thematic analysis technique was followed. An evaluation of the five participating colleges (A-E) demonstrates both converging and diverging patterns across the thematic dimensions of SDT strategies. While all colleges share common challenges, their specific responses and operational realities differ remarkably.

The themes and categories discussed set the foundation for a deeper interpretation of findings in the next chapter, Chapter Seven. The following chapter builds on these findings to develop an SDT framework and to provide practical recommendations.

Chapter Seven: Interpretation of Findings and the Framework for SDT in Higher Education

7.1 Introduction

The preceding chapter analysed data and discussed the findings. This chapter interprets the study findings and provides a framework for SDT in the context of South African higher education institutions. That is, this chapter attaches meaning to the study's findings and subsequently describes how the thesis and the present study contribute contextually, theoretically, and practically to the scholarship and the information systems research field. The research problem is addressed by attaining the study goal and answering the primary research question that drove the study, "*How should sustainable digital transformation strategies and initiatives be realised, evaluated and enhanced, in the context of South African higher education institutions?"*

The chapter is structured as follows: Section 7.2 synthesises and interprets the study's findings, linking how the five themes interact in practice and is organised according to the conceptual research framework's themes: Leadership, Governance, Infrastructure, Digital Pedagogy, and Policy. Section 7.3 consists of five parts, each of which interprets the key findings in line with the research questions. Section 7.4 maps each question and theme to implications of the findings, particularly how the findings answered each research question. Furthermore, the section discusses theory, policy, and practice implications as well as how the findings support or contrast previous literature. Section 7.5 reviews the study limitations. Section 7.6 summarises the chapter.

7.2 Synthesis and interpretation of findings

This section synthesises and interprets study findings from the preceding chapter six. The findings are interpreted relative to the study's conceptual research framework and against the existing literature.

SDT operates as a dynamic, systematic process in South African TVET colleges. The success of pedagogical shifts is not determined solely by technology integration, but is dynamically enabled or inhibited by five interconnected factors: strategic vision and leadership, institutional capacity, change management, digital teaching and learning, and financial and equity considerations.

Findings reveal that progress in SDT is neither linear nor uniform across institutions. Instead, the implementation trajectory consistently reveals a pattern in which capacity and cultural limitations

constrain strategic intent. Rural colleges have exposed gaps in the assumption of uniform infrastructure readiness, forcing the inclusion of equity-driven planning as a core dimension. Findings on legacy LANs and siloed MIS confirm SIS theory's emphasis on systemic alignment (Seidel et al., 2017; Recker, 2023). While college leadership frequently demonstrates clear strategic intent for DT, its execution is routinely hampered by constraints in key areas, such as sustained funding and institutional capacity. This imbalance directly leads to uneven adoption of digital practices and fragmented strategies across the TVET sector.

Cultural and human aspects are equally key in determining digital adoption, as is technology. Efforts of pedagogical innovation are evident, though not fully institutionalised. These informal networks and distributed nodes of practice often carry the learning load when formal systems lag (Hamadi and El-Den, 2024; Mabidi, 2024). For students with limited resources, equity considerations are central. These theoretical and practical insights reconfigure the conceptual research framework to answer the research questions. Consequently, long-term sustainability depends on aligning policy and governance structures rather than ad hoc acquisitions.

The findings yielded five main themes, which were further categorised into subcategories. Findings across the five participating TVET institutions confirm that these dimensions are not isolated but rather operate as mutually reinforcing or limiting factors within the DT process.

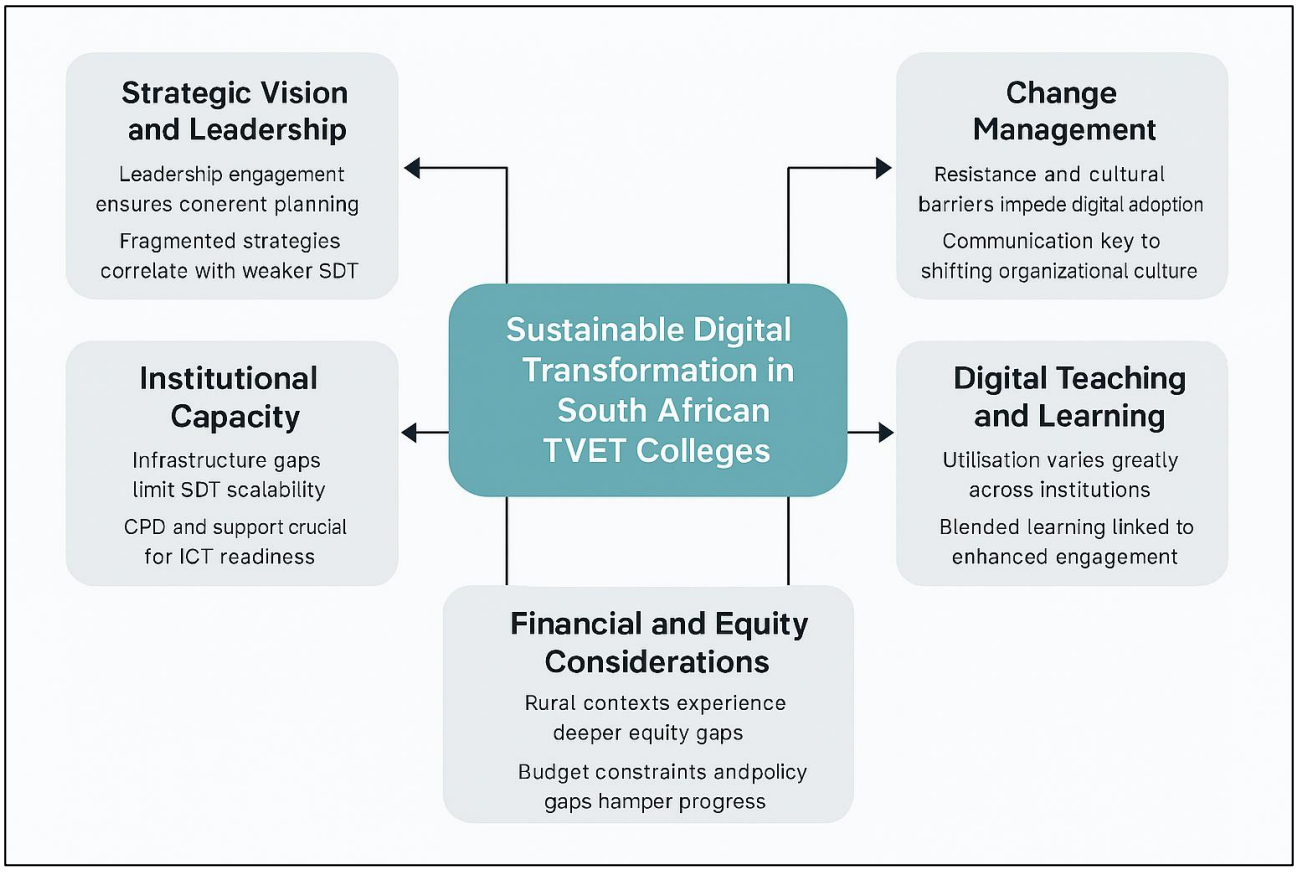


Figure 7.1: Findings relative to the conceptual research framework

Figure 7.1 demonstrates how the empirical findings align with the conceptual research framework (Figure 4.3), a visual conceptual research framework for SDT in South African TVET colleges. The findings stress-test the conceptual framework and evolve it in light of rural-urban disparities, infrastructural thresholds, and equity constraints identified across the five TVET cases.

At the centre of the framework is SDT as a systemic process, surrounded by five interdependent dimensions: Strategic vision and leadership, Institutional capacity, Change management, Digital teaching and learning, and Financial and equity considerations. This framework illustrates the interconnected nature of these five themes; for example, progress in leadership amplifies gains in other areas, such as pedagogy. In comparison, weaknesses in equity gaps may stall the transformation. Figure 7.1 thus affirms the conceptual research framework and highlights its practical relevance in interpreting the empirical landscape.

7.2.1 Strategic vision and leadership

The theme evaluated long-term vision and planning, the evaluation of digital maturity (which is often non-existent or inconsistent), and the active role of leadership in driving SDT. The SIS theory frames the existence of strategic plans that lack cost, sequenced, and risk-managed pathways to execution as a governance and alignment problem. Wherein strategy, technology, people, and processes are

co-designed across their lifecycle (Mustaquim and Nyström, 2014; Recker, 2023). Strategies are reported to be reactive rather than anticipatory. The first tower of the conceptual framework emphasises long-term planning and vision, as well as institutional readiness. The findings demonstrated that while some colleges emphasised clear strategic ambitions in alignment with the national digital skills agendas, translating the vision into operational practice was inconsistent. As the TVET colleges respond coercively to pressures, such as 4IR rhetoric and compliance deadlines.

Institutional theory clarifies why plans remain aspirational as operational resources, decision rights, and routines remain rooted in legacy structures (Aksom and Tymchenko, 2020; DiMaggio and Powel, 1983). Strategic planning often remained limited to high-level documentation, although units such as the ICT department were not regularly included in the early planning phases. Omitting key departments has resulted in infrastructure gaps and underutilised systems.

The framework establishes leadership as the anchor for SDT strategies to shape college priorities and resource allocation. Study findings substantiate this assumption: institutions with strong leadership engagement (Colleges A and B) possess coherent DT strategies and measurable implementation paths, whereas fragmented leadership (Colleges D and E) correlates with reactive planning and limited progress. The framework emphasises distributed leadership and strategic foresight as prerequisites for systematic transformation. A shift in leadership from symbolic signalling to distributed governance is needed to allocate budgets, integrate capacity, and hold relevant departments accountable for delivering (Tustin and van Aardt, 2022; Hamadi and El-Den, 2024).

7.2.2 Institutional capacity

This theme focuses on the operational backbone, comprising infrastructure constraints (outdated devices and inadequate Wi-Fi), human capacity (uneven digital literacy levels and staff turnover), CPD (often generic and lacking technical support), and limited institutional integration or collaboration. The evidence shows that legacy LANs, under-spec devices, intermittent Wi-Fi, and fragile power constrain both administrative digitisation and pedagogy. SIS theory regards these as lifecycle and resilience issues (Klishi, 2023; Recker, 2023). TBL theory treats these issues as factors that refresh cycles; for example, e-Waste and printer paper reduction are environmental-economic trade-offs which must be managed deliberately (Elkington, 2018; Vlachopoulos et al., 2023).

The framework demonstrates infrastructure, human resources, and CPD as operational enablers. Empirical evidence has revealed that while all institutions acknowledge these enablers, colleges vary significantly in their capacity to implement them. Infrastructure gaps, inconsistent CPD, and limited technical support undermine the scalability of digital initiatives, especially in rural contexts (Colleges C and D). Across all college sites, participants reported having to use workarounds, such as using

personal devices or informal support networks, to access resources. As the RBV theory explains, institutions facing challenges such as support ratios and first-line resolution appear thin when upskilled ICT staff are enticed to the private sector. These challenges lead to colleges struggling to convert plans into routines (Freeman et al., 2021; Vandevenne et al., 2023). The findings corroborate the framework's assertions that a TVET college's capacity is foundational, yet vulnerable to resource inequalities.

7.2.3 Change management

The theme covered how organisational culture influences digital integration, also highlighting increased workload, communication gaps, and resistance to change, particularly among senior staff. DT is identified as one of the predominant megatrends shaping 21st-century higher education institutions (Ndaba and Naidoo, 2024). The framework positions organisational culture as a determinant of digital adoption.

Findings reinforce the notion that resistance to change, communication gaps, and entrenched traditional practices hinder the adoption of digital technologies (Timbula and Marvadi, 2023; Abulibdeh et al., 2024). In contrast, where communication is perceived as transparent and leadership visibly supports innovation (Colleges A and B), cultural barriers weaken. Organisational change literature predicts that visible leadership, feedback cycles, and recognition shift norms (Genga and Babalola, 2025). Findings further extend the conceptual framework, wherein staff confidence was reported as uneven, with CPD initiatives often described as generic, irregular, or overly technical, failing to support pedagogical integration (Hamadi and El-Den, 2024).

Another key factor noted was the level of communication. Where leadership communicated clear expectations, including providing follow-up support, staff adoption was high (Martínez-Pérez et al., 2022). In contrast, partial participation in decision-making, unclear messaging, and misalignment of expectations contributed to resistance. This synthesis and interpretation highlight the framework's emphasis on cultural readiness and stakeholder engagement as key levers for DT. This confirms that DT is a cultural shift as much as it is a technological one, and that staff buy-in is central to sustainable implementation.

7.2.4 Digital teaching and learning

The theme explored the DT of teaching and learning practices, including the inconsistent adoption of hybrid and blended learning models and the use of LMSs. Student engagement is noted as positively affected by interactive tools, yet limited by device access and data costs. Furthermore, the findings show that some lecturers use innovative multimodal approaches, including integrating PowerPoint, multimedia, customised apps, and even AI tools such as ChatGPT. These practices enhance learning

outcomes, especially when integrated with interactive or problem-based approaches. The findings critique the linearity of the conceptual research framework as pedagogical transformation is conditional on crossing the infrastructural sufficiency threshold. A further critique of the linearity of the conceptual framework is that connectivism supports networks of content, tools, peers, and feedback nodes that enable learning despite resource asymmetries. This is consistent with reports on uneven readiness and the need to embed sustainability in pedagogy, not only in tools (Sá and Serpa, 2020; Jekabsone and Gudele, 2023; Shenkoya and Kim, 2023).

The conceptual research framework anticipated pedagogical innovation as a core outcome for SDT, emanating from strategic planning and change management (Ajani, 2024; Holler et al., 2023). Evidence established uneven adoption; for example, while Colleges D and E remained reliant on conventional methods, Colleges A and B integrated LMS tools and multimedia resources. Student engagement is demonstrated to improve significantly in contexts where lecturers use interactive digital strategies, which affirms the framework's inclusion of technology-mediated learning as a driver of quality education. However, the reported instances were individualistic and not structured systematically, driven by personal enthusiasm rather than college policy.

7.2.5 Financial and equity considerations

The theme examined budget constraints, structural inequalities, and policy alignment. Significant challenges include the digital divide (rural vs. urban), student device access, substantial policy gaps, and slow operationalisation. Despite uneven infrastructure needs, funding formulas did not differentiate between urban and rural contexts.

The framework highlights equity-driven planning and policy alignment as systematic conditions for sustaining DT strategies. Findings reveal that those persistent financial limitations and structural inequalities, specifically in rural institutions, are widening the digital divide. Literature on South Africa's digital divide and rural disadvantage indicates that uniform funding models amplify disparities without targeted mechanisms (Mhlanga et al., 2022). Although several colleges have initiated zero-rating of LMS platforms, loan schemes, and device access, these efforts often lack long-term financial support. SIS and TBL require sustainability to incorporate social equity and inclusive access, as SDGs 4 and 9 reinforce this responsibility (Caiado et al., 2021; Strielkowski et al., 2022). Policy gaps further compound these challenges, affirming the framework's call for coherent governance and targeted funding models (Tustin and van Aardt, 2022). The evident policy gaps include colleges lacking DT policies, reporting challenges in implementing paperless registration, and digital management of assessments. Literature has highlighted that policy vacuums (e-Assessment, device custody, cybersecurity, e-Waste) hamper coherence (Pascual, 2023; Tshivhase

and Bisschoff, 2023b). In instances where efficient governance structures were in place, such as steering committees chaired by external experts, strategic alignment was stronger.

7.3 Answering the research questions

The preceding interpretation of the empirical findings answers the primary research question and the sub-questions. These interpretations directly address the primary research question by describing how SDT strategies in South African TVET colleges should be realised, evaluated, and enhanced. The findings describe the extent of digital practices across TVET colleges, the degree of strategic implementation, and the systemic constraints that shape DT. Through inductive thematic analysis, the findings demonstrate that SDT is understood and operationalised through a combination of vision, capacity, culture, pedagogy, and equity.

7.3.1 Addressing sub-question 1

The first sub-question concerned the barriers and enablers of SDT strategies, particularly in relation to how the curriculum is delivered and pedagogy is practised. The question explored barriers and enablers that influence the successful implementation of SDT strategies, with a specific focus on integrating digital tools into curriculum delivery and pedagogical practices. The question addressed significant contextual factors influencing the success of SDT strategies, which is essential for understanding sustainability and practical implementation challenges in TVET colleges.

What are the enablers (critical success factors) and the barriers influencing sustainable digital transformation strategies in South African TVET colleges?

The findings revealed that a combination of structural and human factors shapes implementation. Findings identify strong barriers, including infrastructure gaps, financial constraints, resistance to change, and policy misalignment. Infrastructure gaps include limited bandwidth, outdated devices, and sporadic connectivity (intermittent Wi-Fi), while resistance to change encompasses a preference for traditional methods and a fear of increased workload. Further barriers found include financial constraints resulting from dependency on government funding, gaps in staff digital literacy, and high staff turnover rates.

Equally important are enablers such as visionary leadership, structured CPD, and innovative teaching practices. Active leadership engagement involves more coherent initiatives, while innovative lecturers utilise enticing multimedia and apps, leading to improved results. Internal LMS development and integration with business solutions, with targeted budgets, is beneficial as it prioritises student benefits. Other enabling conditions identified include committed ICT teams and

the availability of steering committees. Colleges with proactive leadership and collaborative governance demonstrated higher levels of digital integration compared to those with fragmented leadership.

7.3.2 Addressing sub-question 2

The second sub-question explores and describes the extent of technology use and the governance implications for SDT.

What and how is technology used in TVET colleges to improve higher education, and what are the digital transformation implications for institutional governance? The findings demonstrate a highly varying landscape. Some lecturers do integrate digital tools to support blended learning in innovative ways, including multimedia resources, recorded lessons, and the use of Artificial Intelligence to enhance understanding. These approaches improve student engagement and learning outcomes; however, such teaching practices are sporadic and not the norm across institutions. Some colleges use LMS platforms primarily to upload notes, while others remain reliant on traditional methods such as using chalkboards.

These inconsistent usage patterns, together with interoperability challenges evident in the digitisation of administrative systems and the integration of MIS and ICT platforms, further demonstrate that Themes 1 (Strategic Vision and Leadership) and 2 (Institutional Capacity) have implications for institutional governance. The findings highlight challenges in institutional integration. Instances of these challenges include limited collaboration among MIS, ICT, and academic units, as well as the lack of interoperable digital record-keeping systems. Additionally, decision-making structures, prioritisation of ICT investments, and the effectiveness of communication across organisational levels determine whether technology is used functionally or transformatively.

7.3.3 Addressing sub-question 3

The third sub-question describes the fundamental role and influence of leadership and governance in driving and sustaining DT within TVET colleges in South Africa. Leadership is a pivotal factor in driving and sustaining DT. Leadership and governance are directly aligned with institutional culture and strategic management, supporting sustainability. Thus, leadership and governance are identified as important factors in addressing the third sub-question in shaping SDT trajectories.

How does leadership and governance influence sustainable digital transformation, in the context of TVET colleges in South Africa? Institutions with engaged leadership, clear strategic direction, and distributed decision-making structures were found to have more coherent trajectories of DT strategies

and resource prioritisation. Conversely, passive leadership correlates with reactive planning and limited progress, underscoring the framework's emphasis on governance as a systemic enabler. Additionally, limited involvement of ICT personnel in strategic planning and inconsistent communication creates resistance and uncertainty among staff, thereby reducing the effectiveness of SDT initiatives.

Findings indicate the need for leadership to shift ICT from a secondary to a primary role, ensuring that management expectations align with staff capabilities to secure the necessary budget for sustainability. Findings from institutional leaders, governing boards, and policy advisors provided valuable insights into the strategies, policies, and practices most effective in fostering a culture of innovation, promoting collaboration across departments, and ensuring accountability for DT initiatives.

7.3.4 Addressing sub-question 4

The fourth sub-question sought to determine ways to realise, evaluate and enhance SDT strategies and initiatives for South Africa's TVET colleges. The sub-question draws actionable insights and policy implications from the findings, which are fundamental for the practical application and sustainability of DT efforts in the TVET sector. The sub-question concerns policy recommendations, which are supported by the evidence presented.

How can sustainable digital transformation strategies and initiatives be realised, evaluated and improved in the context of South African TVET colleges? The findings highlight the need for DHET-led operational frameworks that incorporate stakeholder-informed policies and structured capacity-building initiatives. A recommendation based on empirical evidence is to adopt policies that move beyond ad hoc acquisitions to targeted funding models that address rural and socio-economic disparities, necessary to sustain DT. In Theme 5, Financial and equity considerations, findings identified numerous policy gaps, including a lack of DT policies, non-alignment with DHET frameworks, and the absence of device policies. Evidence indicates that many colleges operate with outdated or incomplete policies, especially in areas such as device ownership, digital assessments, and paperless administration. There is a need for policies that address equity gaps, align institutional strategies with national digital agendas, and foster sustainable governance mechanisms. The empirical evidence suggests that without clear systems and protections, digital initiatives remain vulnerable to operational risk, inequitable implementation, and financial insecurity.

7.4 Implications of Findings, Recommendations, and Contributions

Sections 7.4 and 7.5 discuss the implications of findings and subsequently give practical and theoretical recommendations by way of conceptualising a practical and theoretical SDT framework.

The findings show that SDT strategies should be pursued with clear strategic intent, even though implementation varies greatly across TVET colleges. TVET colleges acknowledge the importance of aligning themselves with national digital skills agendas and the broader demands of the Fourth Industrial Revolution. However, the extent to which their ambitions can be translated relies heavily on factors such as institutional capacity, leadership, and contextual constraints. Ultimately, the findings imply a need to empower stakeholders to implement effective, scalable, and sustainable digital initiatives to improve teaching, learning, and governance in TVET colleges. This would support South Africa's transition to a knowledge-based economy.

7.4.1 Potential societal and knowledge impact

The present study findings are poised to make a substantial contribution to both society and the body of knowledge by deepening the understanding of SDT within the context of South African TVET colleges. The present study addresses the pressing need for digital readiness, educator competence, and infrastructural improvements, areas identified as significant constraints in numerous studies and national initiatives (Montenegro-Rueda and Fernández-Cerero, 2023; Chen and Chan, 2024). In evaluating existing strategies and initiatives through a sustainability-focused lens, the present study informs policy and practice, thereby promoting equitable access, skills development, and institutional innovation, which align with the national imperative to upskill youth, enhance employability, and foster inclusive economic growth, all of which are in harmony with the SDGs.

The present study adds to academic discourse in conceptualising a context-specific evaluation and improvement framework for sustainable DT in higher educational settings. Digital initiatives that are effective, scalable, and sustainable, thus enhancing teaching, learning, and governance within TVET colleges, will, in turn, support South Africa's transition toward a knowledge-based economy. The envisioned transition involves research and innovation in digital technology within TVET institutions to foster a culture of curiosity and continuous learning. Additionally, it entails researching TVET DT theories and practices to deepen understanding of their impact and identify areas for improvement (Parua and Yang, 2024). Digital transformation, in conjunction with sustainability measures, holds the potential to markedly enhance institutional competitiveness and operational efficiency, making the insights from this present study highly relevant for policymakers and educational administrators alike. Digital innovation has the potential to support and improve education, making learning more

effective and appropriate, promoting inclusivity, and enhancing the management and organisation of education (Singun, 2025).

7.4.2 Practical and Strategic Implications

The present study informs future scholarly investigations by making significant contributions to the growing field of SDT strategies, especially in the context of South African higher education. Strategically, the present study is designed to assist policymakers in formulating, implementing, and evaluating policies to enhance the integration and effectiveness of SDT strategies in public TVET colleges. The present study informs the development of digital infrastructure, the cultivation of digital literacy among educators and students, and the creation of sustainable digital learning environments. Moreover, the study outcomes are expected to make significant contributions to key theoretical frameworks, such as SIS theory and the IS theory of Sustainability, by providing a robust theoretical foundation for understanding and promoting SDT initiatives. The study findings offer insight into how to create policies that encourage the use of technology in education to close the digital divide and promote equal access to education. The present study encourages policymakers and educational planners, specifically within the South African Department of Higher Education and Training, to embrace proactive, practical strategies to enhance teachers' professional skills in response to digital technologies and the Fourth Industrial Revolution.

7.4.3 Addressing Gaps in Digital Readiness

The present study holds significant societal and knowledge impacts by advancing the understanding of SDT in South African TVET colleges. It addresses critical gaps in digital readiness, educator competencies, and infrastructural challenges, as highlighted in national initiatives (Sheveleva, Mahotin, Lesin and Curteva, 2021). Through evaluating current strategies through the lens of sustainability, the present study informs policy and practice towards enhancing equitable access, skills development, and institutional innovation. The present study provides support for national priorities of upskilling youth, promoting employability, and fostering inclusive economic growth in line with the SDGs. Additionally, it contributes to academic discourse by conceptualising a context-sensitive SDT framework in resource-constrained higher educational settings. The framework has the potential to significantly improve governance, instruction, and learning in TVET colleges, supporting South Africa's transition to a knowledge-based economy and empowering stakeholders to implement sustainable, scalable, and effective digital initiatives. Furthermore, the findings enhance understanding of how TVET colleges in South Africa can sustainably implement DT, thereby addressing significant shortcomings in digital readiness, educator skills, and infrastructure.

7.4.4 Policy and Theoretical Implications

Strategically, the present study supports policymakers in designing, implementing, and evaluating policies that enhance the integration and effectiveness of SDT strategies in public TVET colleges. Digital transformation, combined with sustainability measures, has the potential to improve institutional competitiveness and operational efficiency. The study findings contribute to key theoretical frameworks, including Sustainable Information Systems theory and the Information Systems theory of Sustainability, which serve as lenses for examining how information and communication technologies can facilitate environmental sustainability and social equity. The present study makes meaningful contributions to the emerging field of SDT strategies in South African higher education through practical, methodological, and theoretical advancements. The study argues that skills training programs are more effective when aligned with training policies for workplace changes driven by technology and industrial strategy. This viewpoint emphasises the significance of incorporating digital technologies into community engagement initiatives at local, national, and international levels to promote lifelong learning and broaden education beyond the classroom. This entails understanding the underlying causes, supporting elements, and complex relationships that influence the integration of digital technology in education.

The present study enhances understanding of the driving forces behind DT within the higher education sector by identifying primary, secondary, and tertiary drivers that propel this transformation. The transition of governments, businesses, and societies is supported by DT, and this study presents a case study of South Africa, a developing nation that has adopted this agenda.

Thus, the theoretical and practical contribution of the present study is a new SDT evaluation framework that accounts for the unique challenges and opportunities faced by higher education institutions in South Africa. That is, the conceptualised framework attains the goal of the present study by answering the primary research question, “How should sustainable digital transformation strategies and initiatives be realised*, evaluated and enhanced, in the context of South African higher education institutions?”*

7.5 Conceptualising a Sustainable DT evaluation framework

This section conceptualises and details a context-sensitive SDT evaluation framework. The framework is conceptualised to enable an individual institution to practically diagnose its current position, prioritise what it can focus on, and track sustainable progress over time. The framework answers the primary research question: *How should sustainable digital transformation strategies and*

initiatives be realised, evaluated and enhanced, in the context of South African higher education institutions?

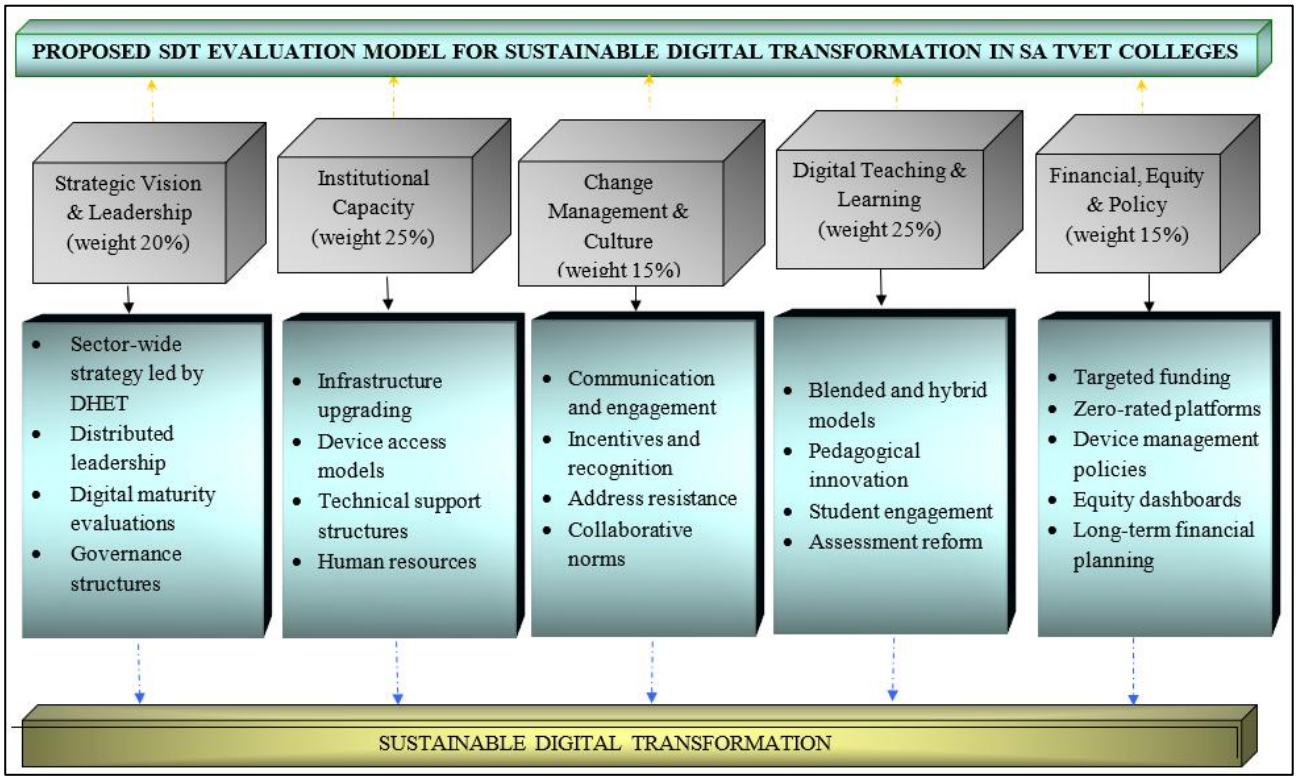


Figure 7.2: A Sustainable Digital Transformation evaluation framework

Figure 7.2 illustrates a framework derived from the five interconnected dimensions or themes empirically identified and described to shape the SDT trajectory in South African higher education institutions. It functions as a systemic process where progress in any one dimension reinforces the others, leading to a more successful and sustainable transformation. The five key dimensions are interconnected and contribute towards the ultimate goal of SDT, in the context of South African higher education institutions.

7.5.1 Overview of SDT evaluation framework

The framework provides systemic, scalable, and context-sensitive elements that may enable SDT across TVET colleges. It acknowledges that transformation is not a technology project but a multidimensional journey, grounded in an institutional change process that requires alignment among the five themes or elements mentioned. The framework emphasises that all five themes must be addressed concurrently and successfully to achieve the outcome. Theme 1: Strategic vision and leadership are positioned as the foundational anchor providing direction. Themes 2 to 4 execute the operations, and Theme 5: Financial and equity considerations dictate the long-term viability and fairness of the process.

7.5.2 Purpose of the SDT evaluation framework

The conceptualised SDT evaluation framework offers a standardised, contextual, theoretical, and practical approach for South African HEIs to realise, assess, and enhance SDT strategies, ensuring they are measurable, equity-aware, and sustainable. As the SDT evaluation framework is systematic and not tool-centric, all five themes or elements can be assessed and enhanced concurrently.

7.5.3 Domains and Core Indicators

In line with literature recommendations, each of the five domains, aligned to the five themes, has subdomains and Core Indicators (CIs) with suggested evidence sources and scoring bands (Kajamaa et al., 2020). Scoring bands (0-4) are: 0 Absent; 1 Emerging; 2 Developing; 3 Established; 4 Optimising (sustained, scaled, evidenced). Each domain utilises CIs to assess maturity, specifying the necessary evidence for verification, and employs a consistent 0-4 scoring system to calculate the institution's maturity level in that area.

7.5.3.1 Domain A: Strategic Vision and Leadership (weight 20%)

The first domain serves as a foundational anchor for the DT, evaluating the institution's leadership's coherence, commitment, and foresight. As illustrated in Table 7.1, this domain focuses on whether the digital strategy is officially approved, integrated into planning (A1), driven by a cross-functional governance body (A2), and informed by genuine stakeholder feedback (A3). Achieving a high score, for instance, a 4, depends on continually reviewing and refining the strategy based on measurable outcomes and transparent reporting, moving beyond mere compliance to proactive, data-driven decisions.

Table 7.1: Strategic Vision and Leadership (weight 20%)

Subdomain	**Core Indicators (CIs)**	**Evidence**	**Scoring cues (0-4)**
A1. Strategy & Roadmap	CI-A1: Approved 3-5 year SDT roadmap with annual milestones; CI-A2: Digital maturity is assessed annually and informs APP or budget	Council minutes; APP; maturity report	0: none; 2: draft exists, not costed; 3: approved & cascaded; 4: reviewed annually with course-corrections

A2. Distributed Leadership	CI-A3: Cross-functional ICT-MIS-Academic Steering Committee active; CI-A4: % departments with SDT KPIs	Committee TOR & attendance; departmental plans	0: siloed; 2: committee exists; 3: meets quarterly with actions; 4: data-driven decisions, transparent reporting
A3. Stakeholder Engagement	CI-A5: Student or lecturer consultation embedded in decisions	Survey schedules; feedback loops	0: ad hoc; 3: structured termly; 4: changes demonstrably shaped by feedback

7.5.3.2 Domain B: Institutional Capacity (weight 25%)

The second domain in Table 7.2 is among the highest-weighted domains. Institutional capacity assesses the institution's operational readiness, the "plumbing", which enables digital activities. It evaluates the physical infrastructure (B1), the seamless flow of data between systems (B2), the adequacy and retention of technical support personnel (B3), and the focus of staff development. A high-scoring institution ensures that training (B4) is not just about tools but is pedagogy-centred and backed by classroom coaching, directly connecting staff competencies to observed practice change.

Table 7.2: Institutional Capacity (weight 25%)

Subdomain	**Core Indicators (CIs)**	**Evidence**	**Scoring cues (0-4)**
B1. Infrastructure & Resilience	CI-B1: % lecture venues "DT-ready" (power, Wi-Fi, projection); CI-B2: Campus WAN uptime; CI-B3: Cloud or backup & cybersecurity posture;	Asset register; NOC logs; ICT policies	0: legacy only; 2: partial coverage; 3: majority venues ready; 4: redundancy & proactive refresh & security audits

	CI-B4: E-waste or device lifecycle policy		
B2. Systems Integration	CI-A3: Cross-functional ICT-MIS-Academic Steering Committee active; CI-A4: % departments with SDT KPIs	Data flows: API or ETL logs	0: manual; 2: partial exports; 3: APIs in prod; 4: automated, low error rates
B3. Human Capacity & Support	CI-B6: ICT: staff support ratio; CI-B7: 1st-line resolution time; CI-B8: retention of ICT talent	Helpdesk stats; HR data	0: overwhelmed; 3: SLA met; 4: proactive support & low churn
B4. CPD (fit-for-purpose)	CI-B9: % lecturers completing pedagogy-centred DT CPD; CI-B10: % CPD with classroom coaching follow-up	HR CPD logs; coaching records	0: tool-only training; 3: termly CPD with coaching; 4: CPD tied to observed practice change

7.5.3.3 Domain C: Change Management and Culture (weight 15%)

The third domain, illustrated in Table 7.3, below, focuses on the human and cultural components of DT. Change Management addresses resistance and fosters a positive, experimental mindset. Indicators evaluate the presence of active DT champions and communities of practice (C1) that facilitate peer-led adoption. Furthermore, this domain assesses clear, frequent communication, transparent accountability for data quality (C2), and the presence of a "safe-to-try" culture that encourages and evaluates structured pilots for scaling (C3).

Table 7.3: Change Management and Culture (weight 15%)

Subdomain	Core Indicators (CIs)	Evidence	Scoring cues (0-4)
C1. Adoption & Mindset	CI-C1: % departments with DT champions; CI-C2: participation in communities of practice	Champion roster; CoP minutes	0: no champions; 3: active CoP; 4: peer-led diffusion, showcase cycles
C2. Communication & Accountability	CI-C3: frequency or clarity of SDT comms; CI-C4: data quality accountability across units	Comms calendar; data quality audits	0: unclear; 3: regular comms; 4: transparent dashboards & role-based accountability
C3. Safe-to-try Culture	CI-C5: # supported pilots with reflection & scaling criteria	Pilot logs; evaluation briefs	0: none; 3: structured pilots; 4: disciplined innovation pipeline

7.5.3.4 Domain D: Digital Teaching and Learning (weight 25%)

Table 7.4 below demonstrates the fourth domain, which carries the highest weight. This domain measures the direct impact of SDT on the core function of higher education institutions, specifically teaching and learning. It moves beyond simple technology availability to assess its effective use (D1), the observed shift to blended active learning practices (D2), and the measurable positive effect on student pass rates and engagement (D3). Significantly, this domain evaluates the institution's provision for equitable remote access and digital support for Work-Integrated Learning (WIL) (D4).

Table 7.4: Digital Teaching and Learning (weight 25%)

Subdomain	Core Indicators (CIs)	Evidence	Scoring cues (0-4)
D1. LMS & Tool Use	CI-D1: Active LMS use (% modules with weekly activity beyond file upload);	LMS analytics; assessment audits	0: repository use only; 2: mixed; 3: interactive with feedback; 4:

	CI-D2: Assessment variety & integrity		data-informed course design
D2. Pedagogical Practice	CI-D3: Observed adoption of blended or active learning; CI-D4: OER use or creation	Lesson observations; OER registry	0: chalk-and-talk; 3: routine blended practice; 4: reflective, student-centred design evident
D3. Learning Outcomes & Engagement	CI-D5: Completion or pass rates in digitally-supported modules vs. baseline; CI-D6: Student engagement (log-ins, submissions, attendance) adjusted for access	MIS outcomes; LMS logs	0: no tracking; 3: outcome gains documented; 4: continuous improvement cycles
D4. Remote & Work-Integrated Learning Support	CI-D7: Remote access arrangements (zero-rating or VPN or data bursaries); CI-D8: Digital support for WIL	MoUs; student support records	0: none; 3: zero-rated LMS or data support; 4: robust, equitable arrangements

7.5.3.5 Domain E: Financial, Equity and Policy (weight 15%)

The final domain, as shown in Table 7.5 below, focuses on the constraints and long-term sustainability factors essential to SDT success. Equity and access (E1) are assessed using the Equity Index (EI), a measure that requires near-universal access and inclusive design to achieve a score of 4. Sustainable financing (E2) ensures that the strategy is costed over the medium term (METF) with diversified funding. Finally, Policy coherence (E3) ensures that foundational policies, ranging from e-assessments and data governance to cybersecurity and e-waste, are not only written but also actively enacted and compliant with national models.

Table 7.5: Financial, Equity and Policy (weight 15%)

Subdomain	Core Indicators (CIs)	Evidence	Scoring cues (0-4)
E1. Equity & Access	**Equity Index (EI)** combining: % students with device meeting min spec; campus Wi-Fi coverage; zero-rating; assistive tech availability; targeted support for rural or semi-rural campuses	Surveys; network maps; procurement	0: high exclusion; 3: majority covered; 4: near-universal access with inclusive design
E2. Sustainable Financing	CI-E2: % SDT budget aligned to roadmap; multi-year TCO planning (capex or opex); external partnerships	Budget; donor or partner MoUs	0: ad hoc buys; 3: costed MTEF plan; 4: diversified, resilient financing
E3. Policy Coherence	CI-E3: Existence & enactment of DT, e-Assessment, device & data governance, cybersecurity, e-waste policies aligned to DHET frameworks; CI-E4: compliance audits	Policy set; audit reports	0: gaps; 3: policies implemented; 4: periodic reviews & compliance evidence

7.5.4 Composite scoring, weighting, and benchmarks

The domain weights are A, 20%; B, 25%; C, 15%; D, 25%; and E, 15%. This distribution reflects that Capacity (B) and Pedagogy (D) are the most significant levers for transformation, with Leadership (A) underpinning and supporting both these levers.

The scoring process involves assigning each Critical Indicator (CI) a simple score of 0 to 4. A domain's overall score is calculated as the simple average of all its CIs. The final composite SDT score for the institution is determined by a weighted sum of the five domain scores, yielding an overall score ranging from 0 to 4.

The Composite SDT Score maps directly to one of the five defined maturity levels. The maturity levels range: Level 0 to 0.9: *Foundational*, 1.0-1.9: *Emerging*, 2.0-2.9: *Developing*, 3.0-3.4: *Established*, and 3.5-4.0: *Optimising (sustained)*.

An equity safeguard is an institution that cannot be rated above "Developing" if the Equity Index (EI) is below 2.0 (indicating insufficient student access). An institution's overall Composite SDT Score cannot be rated above Developing (2.9), regardless of its performance in other domains. This prevents "paper maturity," where strategy and tools advance while students remain excluded.

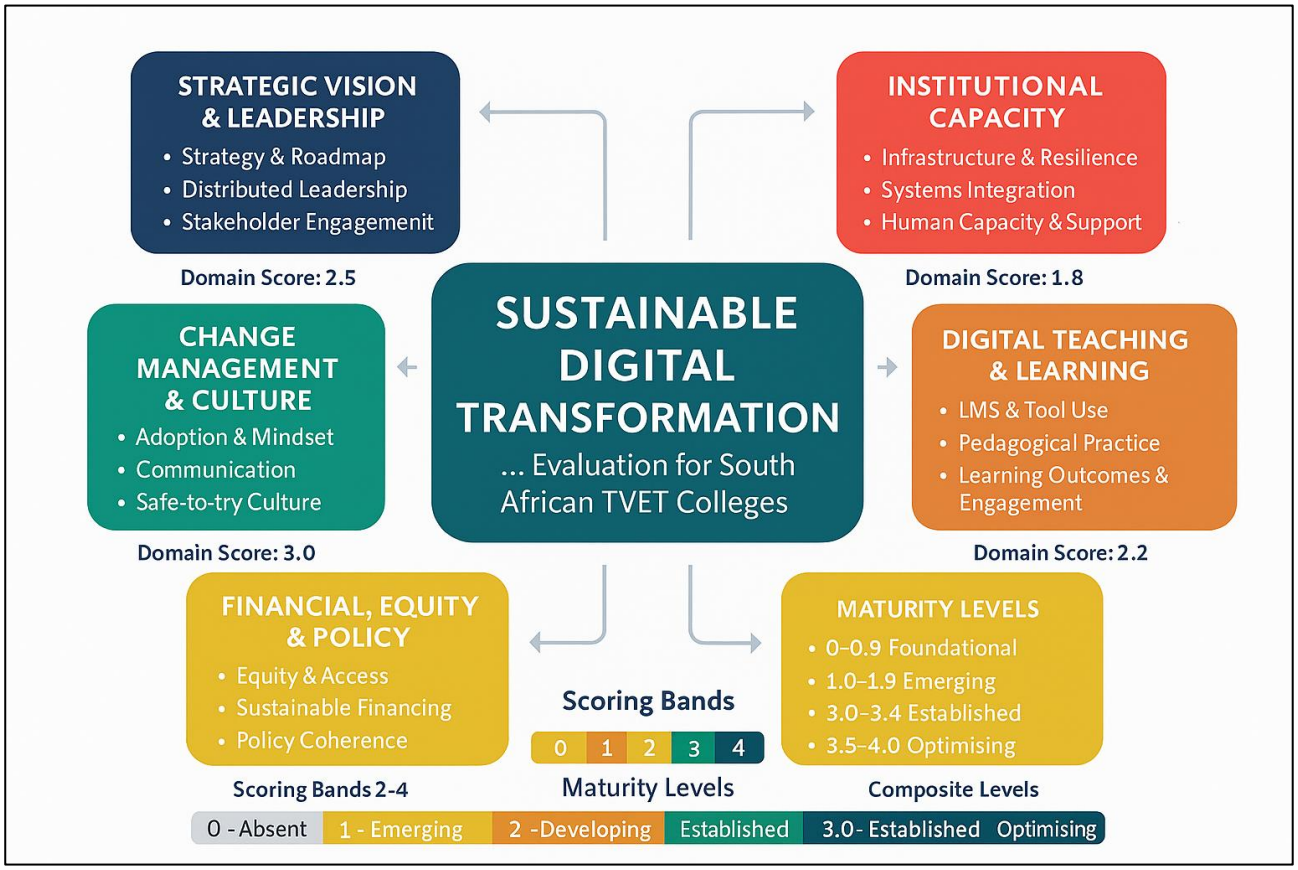


Figure 7.3: The SDT evaluation framework with example scores for each domain

Figure 7.3 illustrates the SDT evaluation framework, accompanied by example scores for each domain. The figure shows the Central SDT panel and the five domains, each of which has an illustrative score number that should be replaced with the actual institution's computed value, for example, Domain Score: 2.5. The bottom of the figure displays the Scoring bands (0 to 4) and maturity levels legend (Foundational to Optimising).

7.5.5 Equity Index and governance

Equity Index (EI) measures whether the DT benefits are equitably distributed. This measurement can be achieved through using the weighted formula below, based on five key components of student access:

EI = 0.30*(DeviceAdequacy) & 0.25*(On-CampusConnectivity) & 0.20*(ZeroRating/DataAid)

& 0.15*(AssistiveTechInclusion) & 0.10*(RuralCampusSupport)

Each sub-component score is rated from 0 to 4 based on preset thresholds. For instance, Device Adequacy receives a score of four if 80% or more of students meet the specifications, a score of two if 40% to 50% of students meet the specifications, and a score of zero if fewer than 20% of students meet the specifications. This computation involves campus-sensitive reporting, which entails reporting the EI by campus, along with an institution-wide average. Furthermore, this step highlights geographical disparities and mandates targeted interventions for rural or semi-rural campuses.

7.5.6 Institutional Data Collection Plan

The framework suggests that data should be collected at varying frequencies: Quarterly, Biannually, and Annually, to ensure timely monitoring of dynamic processes while keeping resource consumption manageable. Table 7.6 below illustrates this data collection plan, with the primary sources depicting the operational systems already in use.

Table 7.6: The institutional data collection plan

Collection frequency	**Data collected (Examples)**	**Primary sources**
Quarterly (Q)	A2 Steering Committee activity B1 uptime and venue readiness B3 helpdesk SLA C2 communications D1 LMS usage analytics D3 engagement E1 network coverage updates	MIS or BMS, LMS analytics, helpdesk system, ICT NOC logs,

Biannual (S1 or S2)	B2 integration tests B4 CPD completion and coaching follow-up C1 champion activity D2 lesson observation samples D4 WIL support checks	HR or CPD records, Council or Committee minutes,
Annual (A)	A1 maturity review and roadmap refresh E2 TCO budget review E3 policy compliance and cybersecurity or e-waste audits student device or data survey for EI	Budget books, policy repository, and short student or lecturer surveys

7.5.7 Evaluation cycle and governance

The framework advocates for the evaluation to follow a continuous Plan-Do-Study-Act (PDSA) cycle, owned and governed through a dedicated SDT Steering committee. The SDT Steering Committee should include the Principal or Deputy Principal, ICT, MIS, Academic heads, Finance, campus representatives, and a student representative. Table 7.7, below, illustrates that this committee should oversee the entire cycle and be responsible for cross-functional accountability.

The domain owners must be the key managers assigned with the responsibility for specific indicators. For instance, ICT owns Infrastructure or Capacity (B) and Cybersecurity (E3), Academic Heads own Digital Teaching and Learning (D), and Finance owns the Budget (E2). For assurance, the internal audit function must review the data integrity of selected indicators annually to ensure the reported scores are reliable.

Table 7.7: The PDSA cycle in practice

Stage	Timeframe	Activities
Plan	Q4 annually	Conduct the maturity self-assessment; update roadmap and budget; set 6-8 specific improvement targets with clear owners and timelines.
Do	Each quarter	Execute planned projects; regularly report a one-page SDT dashboard to the College council, the Senior management team (SMT), and campus heads to maintain visibility.
Study	Biannually	Run evidence review clinics to triangulate data (LMS analytics, student outcomes, and user feedback then adjust implementation strategies based on findings.
Act	Annually	Reweight strategic priorities (e.g., if integration is consistently blocked, shift capital expenditure from integration projects to

		essential LAN or Wi-Fi; if pedagogy is lagging, intensify lecturer coaching).

7.5.8 Implementation Roadmap (12 months)

The purpose of the framework is to provide a common evaluative architecture for sustainable digital transformation. However, the implementation pathway may differ substantially between institutions. Consequently, the roadmap represents one possible implementation scenario rather than a fixed implementation prescription. The first year is crucial for establishing the SDT and to drive immediate impactful changes. In the first quarter, the baseline should be established through the Steering Committee, which will set and approve indicators and weights. Additionally, all CIs should be collected to compute the first baseline. The EI is determined by campus and the first dashboard should then be published.

For the second quarter, focus should be on fixing the plumbing (capacity first), shifting attention to core operational functionality. The top three infrastructure and system integration fixes should be executed. Furthermore, coaching-backed CPD should be launched in two priority academic programmes. Importantly, negotiations for zero-rating LMS and direct student data aid should be initiated.

In the third quarter, the focus should be expanded to digital teaching and learning. Model digital modules are expanded across programmes, and short "micro-pilots" are run to test new tools. A campus-wide “learning festival” should also be held to showcase early successes and promote stakeholder buy-in. Furthermore, policy enforcement for device lifecycles and e-Waste management must be initiated.

In the final fourth quarter, the annual cycle should conclude with consolidation. An assessment should be conducted and repeated to compare the year-end score against the baseline. This 3-5-year roadmap should then be refreshed with new targets, and the Total Cost of Ownership (TCO) for SDT should be formally embedded into the Medium-Term Expenditure Framework (MTEF) budget and APP. Moreover, an external peer review should then be conducted to affirm the process.

7.5.9 Summary of the SDT evaluation framework

The context-specific evaluation framework for SDT in South African higher education institutions offers a practical and theoretically guide for implementation and enhancement of SDT. While progress is uneven, the present study shows clear evidence of innovation, leadership commitment, and pedagogical experimentation across the higher education sector. With sector-wide support,

targeted funding, and coherent governance, South African higher education institutions can transition from fragmented initiatives to strategic, sustainable digital ecosystems that enhance teaching, learning and institutional resilience.

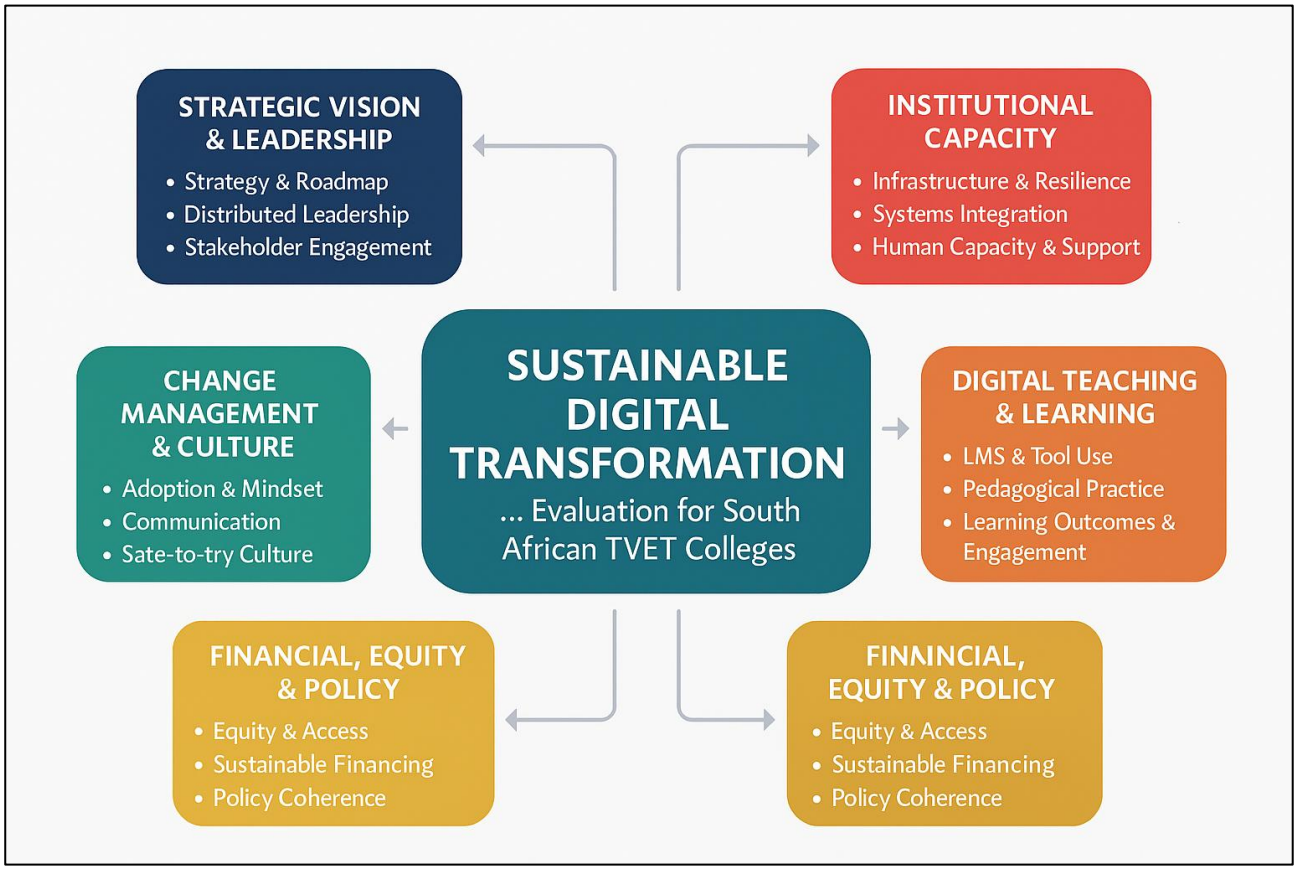


Figure 7.4: Schematic representation of the SDT evaluation framework in SA higher education institutions

From Figure 7.4, it is evident that the evaluation framework effectively addresses the research problem by offering an informed guide to achieving sustainable digital transformation in the context of South African higher education institutions. Leadership should be evenly distributed, resulting in undistributed governance, and infrastructure should receive targeted funding. Staff resistance should be addressed through effective change management, and pedagogical inconsistencies can be mitigated by establishing and adhering to minimum LMS standards. Lastly, the highlighted equity barriers can be countered by zero-rating and device policies. The evaluation framework is thus

implementable, scalable and evidence-based, once embedded in DHET policy briefs and strategic planning documents for higher education councils.

7.6 Chapter summary

This chapter interpreted the study findings and provided a framework for SDT in the context of South African higher education institutions. The chapter attached meaning to the study findings and subsequently described how the thesis and the present study contribute contextually, theoretically, and practically to the scholarship as well as the information systems research field. The research problem was addressed by attaining the study goal and answering the primary research question that drove the study, "How should sustainable digital transformation strategies and initiatives be realised, evaluated and enhanced, in the context of South African higher education institutions?"

Chapter Eight: Evaluation of the Research and Conclusion

The preceding chapter interpreted the study findings in the context of South African higher education institutions and against the existing literature. It addressed the research problem and subsequently described how the present study contributes to the information systems scholarship and practice. This chapter evaluates and reflects on the research journey. The thesis contributions are further discussed.

The chapter is structured as follows: Section 8.1 provides an overview of the study. Section 8.2 restates the research goal and the research questions, while Section 8.3 provides key findings and the summarised SDT evaluation framework, followed by Section 8.4, which outlines the study limitations. Section 8.5 outlines future research directions, and the thesis concludes.

8.1 Overview of the study

The present study was motivated, in part, by published views that argued that institutions should build competitive advantages and develop a sustainable education management strategy (Mohamed Hashim et al., 2022a). The present study was further motivated by the need for HEIs to possess a comprehensive understanding to harness their current SDT strategies across teaching, learning, and research. Effective technology integration and global competitiveness ensure that higher education graduates are fully prepared for the 21st-century workforce (Castro Benavides et al., 2022; Stroumpoulis and Kopanaki, 2022).

To attain the study goal and contribute meaningfully, the thesis was organised as follows: **Chapter one** introduced and provided the background to the study. It gave the background to the field studied, the background to the research problem, which provided the motivation for the present study. The chapter identified the research knowledge gaps and provided the research problem. The study's purpose, goal, objectives, and research questions were outlined. Finally, the study delimitations and significance of the study were provided. **Chapter Two:** Sustainable Digital Transformation in Higher Education Institutions and Related Works surveyed the scholarship and systematically reviewed literature that gave the theoretical and practical foundation for the present study. **Chapter Three:** Landscape of the South African TVET sector and Related Works surveyed the scholarship and systematically reviewed literature that further gave the theoretical and practical foundation for the present study. **Chapter Four:** Underpinning Theories and the Conceptual Research Framework for SDT in South African HEIs discussed the underpinning theories and provided the conceptual research framework that guided the present study. **Chapter Five:** Research Methodology describes the

research methodology followed in conducting the present study. **Chapter Six:** Data Analysis and Discussion of Findings thematically analysed data and discussed the study findings. **Chapter Seven:** Interpretation of findings and the SDT framework interpreted the study findings and provided the framework for evaluating and improving SDT strategies, in the context of South African higher education institutions. The contributions of the study were discussed. This **Chapter Eight** evaluates the research journey, thesis contributions, and concludes the thesis.

8.2 Summarising the framework and the thesis contributions

Rather than "validating" the conceptual research framework, the empirical evidence reshapes it. SIS theory explains why systemic alignment, lifecycle constraints, and governance artefacts are decisive. The revised framework, therefore, makes pedagogy conditional on infrastructural sufficiency and connectivity supports; installs an Equity Index cap; converts leadership into distributed governance with budget and audit trails; and advances policy enactment and integration as operative layers. In the South African higher education institutions context, particularly for rural and semi-rural campuses, these adjustments transform the framework from a generic alignment model into a context-aware, equity-first, and sustainability-anchored framework that better predicts, guides, and evaluates SDT strategies.

Taken together, the empirical evidence demonstrates that DT progress is systemic rather than linear. Leadership sets intent, but infrastructure and human capacity determine the feasible ceiling. As culture determines adoption speed, pedagogy is reflected through the combined effect of these factors. Lastly, equity ultimately decides who benefits. Where leadership couples vision with distributed governance, costed roadmaps, plumbing fixes, coaching-centred CPD, and equity safeguards, digital practices take root and begin to improve outcomes. Where any of these links fail, DT remains a set of pilots rather than a sustained transformation.

The empirical evidence converges on five highly interconnected themes:

- **Strategic Vision and Leadership**
  Leadership sets the tone for digital transformation. However, vision must be operationalised through coherent governance, resourcing, and continuous oversight.
- **Institutional Capacity**
  Digital transformation cannot progress without sufficient infrastructure, technical expertise, and aligned systems. Gaps in connectivity, hardware, and digital support hinder pedagogical innovation.
- **Change Management and Organisational Culture**

Resistance to change persists where communication is weak and professional development is irregular. Organisational culture - not technology - determines the pace and depth of digital adoption.

- **Digital Teaching and Learning**
  When supported, educators demonstrate creativity and innovation in their use of digital tools. Yet these practices remain uneven and overly dependent on individual champions.
- **Financial and Equity Considerations**
- Funding models insufficiently address rural-urban disparities, raising concerns about digital inequality. SDT cannot succeed without addressing systemic inequities in access and opportunity.

These five themes strengthen the argument that digital transformation is a systemic, whole-institution process, and must be evaluated as such.

8.4 SDT evaluation framework

The primary contribution of the present study is the development of the SDT Evaluation Framework, conceptualised specifically for the South African higher education institutions context. The framework integrates national policy mandates, institutional leadership, technical capacity, organisational culture, digital pedagogies, and equity considerations. It illustrates how SDT progresses through interlinked pillars and identifies conditions under which sustainable outcomes are most likely to occur.

More than a theoretical construct, the framework serves as a practical guide for higher education institutions to plan, realise, monitor, and evaluate their digital transformation journeys.

8.4.1 The SDT evaluation diagram

The SDT evaluation framework for South African higher education institutions, presented below, conceptualises DT as a multi-layered, interdependent process anchored in leadership and guided by national and institutional mandates. The framework follows a logical flow from inputs through foundational and enabling pillars to final measurable outputs. Each dimension interacts with the others, reinforcing or constraining progress.

At the top of the framework lies the SDT Input, driven by national and institutional mandates such as DHET policy directives, strategic plans, and budget allocations. Beneath this sits the Foundation (The

Anchor), which encompasses Strategic vision and leadership, determining direction, coherence, and resource prioritisation. Weakness at this level results in fragmented, reactive digital initiatives.

From the foundation arise three core pillars: Pillar 1, Institutional Capacity, which captures the infrastructural and technical capabilities required to support transformation. Pillar 2: Change Management, representing organisational culture, digital literacy, communication channels, and readiness for change. Pillar 3: Digital Teaching and Learning, reflecting the integration of digital tools and pedagogies into the core functions of curriculum delivery and student learning.

Running across all components is a Cross-Cutting Constraint: Financial and Equity Considerations, representing budget limitations, rural and urban disparities, policy gaps, and equity of access. This constraint either enables or restricts each pillar and the overall sustainability of DT. The flow concludes with the Output: Sustainable Digital Transformation and Improved Student Outcomes, measured through indicators such as digital maturity, employability, and academic success rates. Ensuring that student data is protected while utilising digital technology tools is a critical challenge that institutions must navigate to maintain trust and compliance with regulations. This SDT evaluation framework, depicted in Figure 8.1, is the core output of this present study.

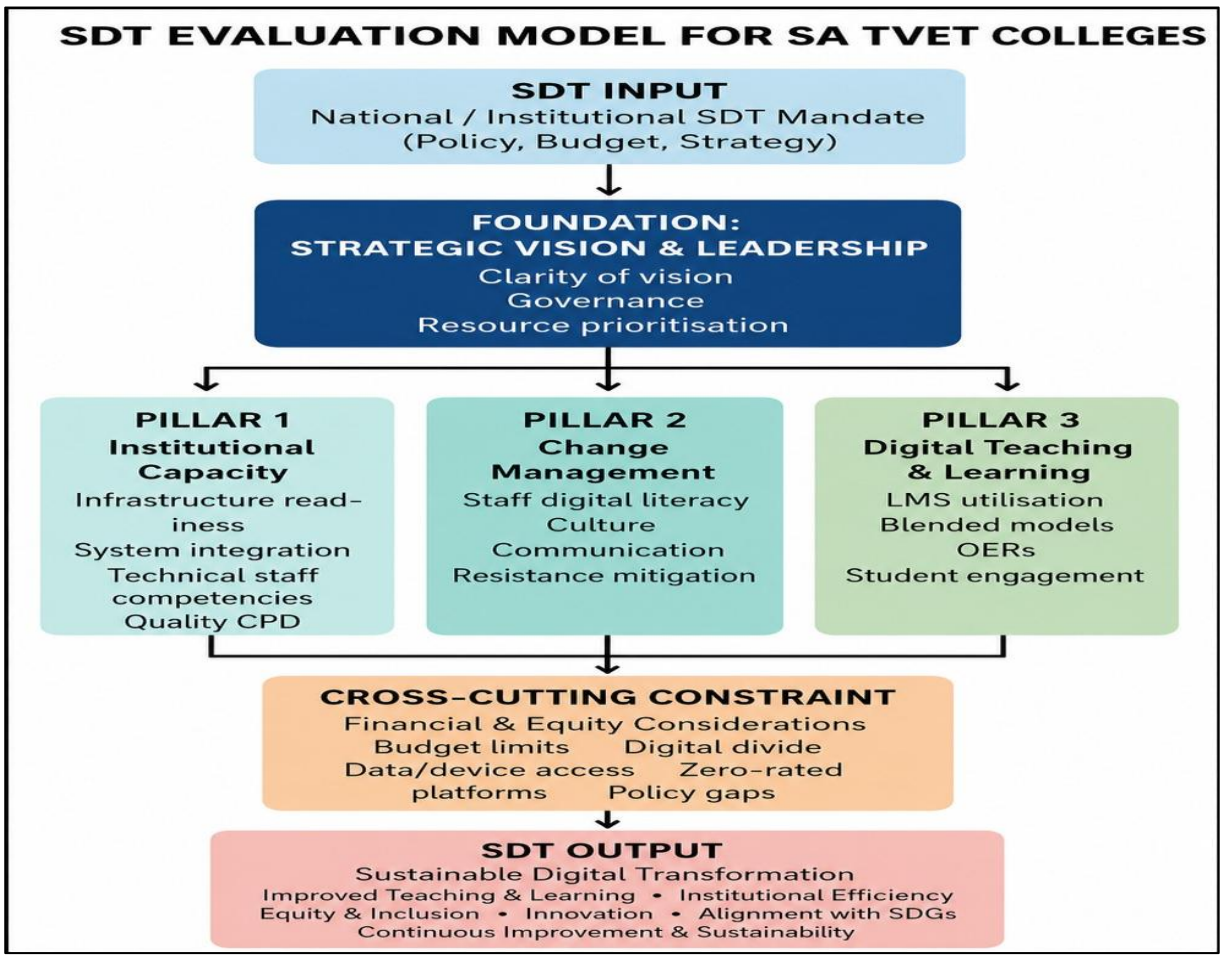


Figure 8.1: SDT Evaluation Framework for South African Higher Education Institutions

8.4.2 The five Pillars of the SDT evaluation

Table 8.1: SDT evaluation framework elements

Model Component	Description	Key focus area
Input	The initiating factor for transformation, driven by policy and strategic mandates.	National or Institutional SDT Mandate (Policy, Budget, Strategy)
Foundation (The Anchor)	Core dimension that drives and provides mandate for all efforts; failure results in fragmented implementation.	Strategic Vision and Leadership (Clarity of vision, resource prioritisation, governance structure)
Pillar 1	Physical and technical ability to support digital initiatives.	Institutional Capacity (Infrastructure readiness, integration, technical staff competencies, quality of CPD)
Pillar 2	Socio-cultural readiness for organisational change.	Change Management (Staff digital literacy, organisational culture, communication, resistance mitigation)
Pillar 3	Practical implementation of digital tools in core teaching and learning activities.	Digital Teaching and Learning (LMS use, blended learning, OERs, student engagement)
Cross-Cutting Constraint	Dimension that affects sustainability and equity across all components.	Financial and Equity Considerations (Funding limits, urban/rural divide, device/data access, zero-rating, policy gaps)
Output	Measurable outcomes of transformation efforts.	SDT & Improved Student Outcomes (Digital maturity, employability, student success rates)

8.5 Thesis Contributions to the Information Systems Field

The thesis contributes to the information systems research and practice theoretically, practically, methodologically, and contextually.

8.5.1 Practical contribution

The present study holds strategic significance for policymakers, institutional leaders, and practitioners seeking to implement and sustain DT in higher education institutions. Empirical evidence may support decision-making, resource allocation, and strategic planning. Additionally, the study may empower policymakers to formulate, execute, and assess policy measures aimed at seamlessly integrating and maximising the efficacy of SDT strategies within higher education institutions. The incorporation of digital technologies and sustainability measures has the capacity to provide various advantages to institutions, potentially enhancing their competitiveness. The conceptualised framework serves as a foundation for designers and practitioners to assess the effectiveness of SDT strategies within South African higher education institutions. It offers a context-sensitive framework that can guide decision-makers, institutional planners, and policymakers in evaluating and enhancing SDT initiatives. Through exploring key gaps in digital readiness, educator proficiency, and infrastructure, the present study contributes to both policy and practice aimed at improving equitable access, CPD, and institutional innovation.

8.5.2 Theoretical contribution

In evaluating SDT strategies in South African higher education institutions, the present study triangulated varied theoretical lenses, including the Resource-Based View, the Triple Bottom Line, Sustainable Information Systems theory, and Institutional Theory. There exists potential to advance these theoretical perspectives by providing empirical evidence, practical insights, and a nuanced understanding of the factors influencing sustainable DT in the specific context of South African higher education institutions. The present study applied these theoretical lenses to describe how the unique resources and capabilities related to DT are developed, deployed, and leveraged within the educational context, aligning notably with RBV's focus on institution-specific resources. The present study provides insights into how educational institutions can achieve a balanced and sustainable approach to DT through the three TBL pillars of sustainability. The study reveals the mechanisms through which higher education institutions can effectively navigate and manage institutional change for sustainable DT, applying Institutional theory, among others. It contextualises Sustainable Information Systems theory within a resource-constrained educational environment, expanding its relevance to the Global South.

8.5.3 Methodological contribution

In addition to the theoretical and practical contributions, the present study also yields a methodological contribution. The study is a replicable, qualitative, multiple-case study research that offers a thick description of SDT strategies in higher education institutions, not just numbers. Following an interpretivist philosophy offers insights as experienced in a real-life context. The

research methodology followed is deemed the most appropriate to evaluate and understand the sustainable digital transformation phenomenon. In applying a multiple-case study strategy and thematic analysis, the study demonstrates how interpretive approaches reveal the lived realities, power dynamics, and contextual nuances shaping an institutional digital transformation journey.

8.6 Limitations of this study

Although this study provides valuable insights into SDT strategies within the South African TVET sector, several limitations should also be acknowledged.

Firstly, the study was limited by time and resource constraints, which restricted the number of participating institutions. Only five TVET institutions were included, which seems adequate for a qualitative multiple-case study. This reduces the breadth of institutional diversity that could otherwise enhance comparative depth.

Secondly, participation was limited by the availability of suitable participants. Some potential respondents declined or were unavailable due to workload pressures, college commitments or academic calendar constraints. This resulted in some institutional perspectives not being captured by the study.

Thirdly, the study relied on only qualitative data, drawing on participants' perspectives, experiences, and interpretations. While this approach offers rich contextual understanding, it limits the ability to quantify the degree of adoption for SDT strategies or statistically generalise the findings across the South African TVET sector.

Fourthly, the research design was cross-sectional and not longitudinal. As a result, data collection occurred at a single point in time. This restricted the ability to observe SDT strategies and sustainability initiatives as they evolved, matured, and/or declined over time. A longitudinal design may have revealed dynamic staff perspectives and shifting institutional changes.

Fifthly, the study focused only on institutions already involved in the DHET-driven sustainability or digital transformation programmes (the S4GJ and related initiatives). This purposeful selection increased relevance but might have introduced a positive-outcome bias, as these institutions may already have been more advanced or motivated than institutions without similar exposure.

Lastly, the findings are context-specific and may not be transferable to other post-school institutions, such as private TVET colleges, community colleges, and universities. The distinctive governance

structure, resource environments, and policy restrictions within the TVET college sector limit broader generalisations.

8.7 Future Research Directions

Future work should explore longitudinal implementation of the SDT framework to track digital maturity and student outcomes over time. Comparative studies with TVET systems in other African countries would offer valuable insights into cross-contextual applicability. Mixed-methods designs incorporating cost–benefit analyses, environmental sustainability indicators, and systems-modelling approaches could expand understanding of SDT's long-term institutional impact. Furthermore, comparative studies within the Higher education landscape, such as Universities versus TVETs.

8.8 Conclusion

The present study has addressed the research problem by conceptualising a framework for sustainable digital transformation strategies in the context of South African higher education institutions. The challenges and issues, as well as the identified research knowledge gaps, discussed in the introductory chapter, have now been bridged. The thesis has provided an empirically informed understanding of the current sustainability conditions and the implications of DT strategies in the higher education environment. The research problem was that HEIs lack the "know what" and the "know how" for sustainable digital transformation strategies. Existing literature was deemed inadequate to address this problem. With this thesis, HEIs now possess a comprehensive understanding to be able to harness their current SDT strategies across administration, teaching, learning, and research. The thesis provides sufficient knowledge and understanding concerning the utilisation of technology in higher education institutions and the extent to which sustainable DT could influence the outcomes of administration, teaching, learning, and research. The present study has addressed potential obstacles to sustainable digital transformation and has determined ways for an institution to effectively realise, evaluate and enhance digital transformation; that is, ways to incorporate technology to stay abreast of global trends.

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Appendices

Appendix A: Formal ethical clearance from UNISA

UNISA university of south africa

College of Science, Engineering and Technology_ School of Computing_ERC

NHREC Registration # : (if applicable)
Ref #: 3430
Name: Mr Bakang Nthutang
Student #: 44594925
Staff #:

Date: 14/10/2024

Dear: Mr Bakang Nthutang

Decision: Ethics Approval from 14/10/2024 to 14/10/2029.

Researcher: Mr Bakang Nthutang

28 Pioneer Ave, Florida Park

Rooderpoort, 1709

44594925@mylife.unisa.ac.za 0832497321

Supervisor: Dr Phahlane Mampilo Phahlmm@unisa.ac.za

Co-Supervisor:

Co-Researcher(s):

Email address:

Towards an evaluation of Sustainable Digital Transformation Strategy in South African Higher Education Institutions

Qualification: PhD (Information Systems) 98804

Thank you for the application for research ethics clearance by the College of Science, Engineering and Technology_ School of Computing_ERC for the above mentioned research study Ethics approval is granted for three years.

The **low risk application** was **reviewed** by College of Science, Engineering and Technology_ School of Computing_ERC on 14/10/2024 in compliance with the Unisa Policy on Research Ethics and the Standard Operating Procedure on Research Ethics Risk Assessment.

The proposed research may now commence with the provisions that:

1. The researcher(s) will ensure that the research project adheres to the values and principles expressed in the UNISA Policy on Research Ethics.
2. Any adverse circumstance arising in the undertaking of the research project that is relevant to the ethicality of the study should be communicated in writing to the College of Science, Engineering and Technology_ School of Computing_ERC.
3. The researcher(s) will conduct the study according to the methods and procedures set out in the approved application.
4. Any changes that can affect the study-related risks for the research participants, particularly in terms of assurances made with regards to the protection of participants' privacy and the confidentiality of the data, should be reported to the Committee in writing, accompanied by a progress report.

Page 1 of 2

5. The researcher will ensure that the research project adheres to any applicable national legislation, professional codes of conduct, institutional guidelines and scientific standards relevant to the specific field of study. Adherence to the following South African legislation is important, if applicable: Protection of Personal Information Act, no 4 of 2013; Children's act no 38 of 2005 and the National Health Act, no 61 of 2003.

6. Only de-identified research data may be used for secondary research purposes in future on condition that the research objectives are similar to those of the original research. Secondary use of identifiable human research data requires additional ethics clearance.

7. No field work activities may continue after the expiry date (14/10/2029). Submission of a completed research ethics progress report will constitute an application for renewal, for Ethics Research Committee approval.

Additional Conditions

1. Disclosure of data to third parties is prohibited without explicit consent from Unisa.
2. De-identified data must be safely stored on password protected PCs.
3. Care should be taken by the researcher when publishing the results to protect the confidentiality and privacy of the university.
4. Adherence to the National Statement on Ethical Research and Publication practices, principle 7 referring to Social awareness, must be ensured: "Researchers and institutions must be sensitive to the potential impact of their research on society, marginal groups or individuals, and must consider these when weighing the benefits of the research against any harmful effects, with a view to minimising or avoiding the latter where possible." Unisa will not be liable for any failure to comply with this principle.

Note

The reference number 3430 should be clearly indicated on all forms of communication with the intended research participants, as well as with the Committee.

Kind regards,



Dr. Danie Bisschoff
Chair of College of Science, Engineering and Technology_ School of Computing_ERC
E-mail: Dbischof@unisa.ac.za

Prof SJ Johnstone
Executive Dean / By delegation from the Executive Dean of College of Science, Engineering and Technology_ School of Computing_ERC
E-mail: johnssj@unisa.ac.za

Appendix B: Approval from Gatekeeper

DHET 004: APPENDIX 2: APPLICATION FORM FOR ORGANISATIONS TO CONDUCT RESEARCH IN PUBLIC COLLEGES

FOR OFFICIAL USE

The Qualitative evaluation of Sustainable Digital Transformation Strategy in South African Higher Education Institutions

DECISION BY HEAD OF COLLEGE

Please tick relevant decision and provide conditions/reasons where applicable		
Decision		*Please tick relevant option below*
1	Application approved	
2	Application approved subject to certain conditions. *Specify conditions below*	
3	Application not approved. *Provide reasons for non-approval below*	X
	• Confidentiality around Boland College, staff and students are maintained. • Provide us with a copy of your research report once completed and approved. • Providing that you make arrangements with Dr Liza Hamman (Acting Campus Manager – lizah@bolandcollege.com) and Mr Andries Venter (MIS Manager – andriesv@bolandcollege.com) with regard to your survey.	

NAME OF COLLEGE	BOLAND TVET COLLEGE
NAME AND SURNAME OF HEAD OF COLLEGE	CA GOODWIN
SIGNATURE	
DATE	17-06-2025

Signature:

Email: charlesg@bolandcollege.com

higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

Let the future be known

Ref: UMF 01/06/2025 **Date: 23/06/2025**

University of South Africa
Department of Information Systems
28 Pioneer Ave,
Florida Park
Rooderpoort, 1709

Dear Sir/Madam

RE: PERMISSION TO CONDUCT RESEARCH AT UMFOLOZI TVET COLLEGE FOR PhD (Information Systems) Research

1. Following your application to conduct research on the ***"The Qualitative evaluation of Sustainable Digital Transformation Strategy in South African Higher Education Institutions"***, I am pleased to inform you that you have been granted permission to conduct research at uMfolozi TVET College as proposed.

2. In undertaking this research, you agree to respect and abide by all rules and regulations for conducting research at uMfolozi TVET College.

3. Upon completion of your study, you are requested to submit a summarised copy of the findings of any report or dissertation to uMfolozi TVET College.

Yours Sincerely

Date: 23/06/25

TE Nxumalo

Acting College Principal

Private Bag X5023, Richards Bay 3900, Tel: +27 (35) 902 9501, Fax: +27 (35) 789 2585, www.umfolozicollege.co.za
SERVING COMMUNITIES IN ILEMBE, UTHUNGULU & UMKHANYAKUDE DISTRICTS

higher education & training
Department: Higher Education and Training
REPUBLIC OF SOUTH AFRICA

NCR TVET COLLEGE

Central Office PO Box 1834 Upington 8800
Tel: 087 188 2061 Fax 054 331 1183 Email: percys@ncrtvet.co.za

REF: CEO/DPA/UNISA/RESEARCH/01

ENQUIRIES: percys@ncrtvet.co.za

OFFICE OF THE PRINCIPAL

Date: 25 June 2025

To: Mr Bakang Nthutang
Student Number: 4459-492-5
Email: 44594925@mylife.unisa.ac.za; nthutb@unisa.ac.za; nthutatng@gmail.com

Copy To:
Prof MM Sepota
Acting Registrar
University of South Africa (UNISA)
Department of Information Systems

RE: APPROVAL TO CONDUCT RESEARCH AT NCR TVET COLLEGE

Dear Mr Nthutang,

I am pleased to inform you that your application to conduct research at NCR TVET College has been APPROVED.
Research Title: "The Qualitative evaluation of Sustainable Digital Transformation Strategy in South African Higher Education Institutions"
You are authorized to conduct the following research activities at our institution:

- Individual interviews with MIS Manager, IT Manager, and Campus Manager
- Focus group discussion with Post-Level 2 or 3 Lecturer

Conditions:

1. All research activities must be scheduled in consultation with relevant departments
2. Ethics clearance certificate must be provided before commencement
3. Participant confidentiality and voluntary participation must be maintained
4. A research summary must be provided to the college upon completion

This approval is valid for the 2025 academic year and can be extended upon request.

We wish you success with your doctoral studies.

Yours sincerely,

Mr. P. SAGO
PRINCIPAL

www.ncrtvet.co.za

Business / Skills Unit	Upington Campus	Kathu Campus	Kuruman Campus	Namaqua Campus	De Aar Campus
Tel: 054 331 2589	Tel: 054 332 4711	Tel: 053 723 3281	Tel: 053 712 1691	Tel: 027 744 1360	Tel: 053 631 0594
Fax: 054 331 0033	Fax: 054 332 4958	Fax: 053 723 3091	Fax: 053 712 0980	Fax: 027 744 1603	Fax: 053 631 0617

higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

PORT ELIZABETH TVET COLLEGE

The office of the Campus Manager, Mr. DT Velapi
Russell Road Campus – PETVET College
139 Russell Road, Central
Port Elizabeth, 6001
Telephone: 041 509 6301
E-mail: davidv@pec.edu.za

RESEARCH PROJECT

Dear Mr Bakang Nthutang

This serves to inform you that permission was granted to you by Port Elizabeth TVET College to conduct your research on "Towards an evaluation of Sustainable of Digital Transformation Strategy in South African Higher Education Institutions."

Please inform my office two weeks in advance before you start conducting your study and adhere also, to the conditions laid out in the DHET 004, APPENDIX 1.

Yours Faithfully

Mr. DT Velapi
Campus Manager
Russell Road Campus



Dear Bakang

My huge apologies for the delay in response.

I was not able to access the audience profile you require for your research. We have been engaged in Strategic Planning sessions for the past two months and campus managers were required to develop and submit their campus business plans.

They are now more available and I will be sending them the information you require.

I trust you will find this to be in order.

Warm Regards.

Dear Mr. Nthutang

I trust this message finds you well.

We refer to the email sent to Mr. Hewana on 13 June regarding your request to conduct research at Eastcape Midlands TVET College (EMC).

Please note that the College has already approved a number of research activities involving our students. As your proposed focus areas would require substantial input from lecturers, management and students, many of whom are already engaged in ongoing research projects, the current workload on our internal stakeholders makes it unfeasible to accommodate additional research at this time.

Regrettably, we are unable to approve your request. We do, however, wish you every success in your studies and future research endeavours.

Kind Regards

Elmari van de Merwe (on behalf of Mr Van Heerden, EMC Principal)

higher education & training
Department: Higher Education and Training
REPUBLIC OF SOUTH AFRICA

Eastcape Midlands TVET College
EMC
creating new futures

Elmari vd Merwe |
Assistant Director: Office Management

T: 041 995 2053 | C: 082 772 5906 | E: elmari@emcol.co.za
W: www.emcol.co.za

Appendix C: Informed consent form

CONSENT TO PARTICIPATE IN THIS STUDY

I, _____ (participant name), confirm that the person asking my consent to take part in this study has told me about the nature, procedure, potential benefits and anticipated inconvenience of participation.

I have read (or had explained to me) and understood the study as explained in the information sheet.

I have had sufficient opportunity to ask questions and am prepared to participate in the study.

I understand that my participation is voluntary and that I am free to withdraw at any time without penalty (if applicable).

I am aware that the findings of this study was processed into a research report, journal publications and/or conference proceedings, but that my participation was kept confidential unless otherwise specified.

I agree to the recording of the Interview.

I have received a signed copy of the informed consent agreement.

Participant Name and Surname…… (please print)

Participant Signature……..Date……

Researcher's Name and Surname…… (please print)

Researcher's signature……..Date……

Appendix D: Interview schedule

The semi-structured interview schedule consists of an initial stage in which the participant is prepared for the interview:

1. PREPARING THE INTERVIEWER TO CONDUCT THE INTERVIEWS

- Ensure to have a counsellor and the supervisor on standby should any adverse event occur (where applicable).
- Be mindful of the typical signs of distress that can inform the presence of stress or uncomfortableness with the participants (where applicable).

2. INITIAL STAGE OF PREPARING THE PARTICIPANT

In this stage the participants are prepared for the interview by setting them at ease, as well as informing them of the following:

a. Their rights as participants in the research.
b. The purpose of the interview.
c. The reason for their selection.
d. The anticipated duration of the interview.
e. That consent must be of their own free will.
f. Should the participant feel uncomfortable at any point in the interview, they should please notify the researcher so that the cause of the uncomfortableness can be addressed.
    i. The researcher will have a counsellor on standby should the participant need support services (I applicable);
    ii. The online interview schedule time, if in person, was the choice of the participant;
    iii. The researcher was very sensitive and will ensure the participants video is on whilst conducting the interviews so that the researcher can observe their behaviour and detect any possible signs of discomfort or distress. The researcher will also frequently check in with the participants if they are still fine and ready to continue with the interviews;

iv. The researcher will have their supervisor on standby should any instance occur, for an additional source to refer to, to ascertain the best course of action to protect the participant, the researcher and to ensure data is collected ethically;
v. The researcher advice the participant to always have refreshments such as water and tissues available;
vi. The researcher will make it clear that the participant may take a break when needed and if the participant prefers that the interview be sectioned in shorter sessions;
vii. The researcher will strive to develop a positive regard throughout the interview.

3. INTERVIEW ITSELF

In this section the open-ended questions I intend to ask the participants:

3.1 **Background Information**

General Information: Explore existing digital transformation initiatives within the institution.

- Name:
- Position/Title:
- Institution:
- Years of Experience in Higher Education:

3.2 **Digital Transformation Strategies**

Understanding Current Strategies: Explore existing digital transformation initiatives within the institution.

- How would you define "sustainable digital transformation" in the context of higher education?
- How is the institution currently leveraging digital technologies for teaching, learning, and research processes?
- What specific strategies or tools are in place?

Challenges and Opportunities: Discuss challenges faced during implementation and opportunities for improvement.

- What obstacles hinder successful digital transformation?
- How can these challenges be addressed to ensure the successful implementation of sustainable digital transformation strategies?

- Are there untapped opportunities for enhancing digital strategies?

3.3 Effectiveness Assessment

Measuring Impact: Assess the effectiveness of digital transformation strategies.

- What metrics or indicators are used to evaluate success?
- How do these strategies impact student learning outcomes, faculty productivity, and institutional efficiency?

Stakeholder Perspectives: Gather insights from various stakeholders (academics and non-academics).

- How do faculty members perceive the impact of digital tools on teaching and research?
- What feedback have students provided regarding digital learning experiences?
- Are administrators satisfied with the outcomes?

3.4 Sustainability and Scalability

Long-Term Sustainability: Explore the sustainability of digital initiatives.

- How are these strategies funded and maintained over time?
- What plans are in place to ensure their longevity?

Scalability: Discuss scalability beyond pilot projects.

- Can successful strategies be replicated across departments or the entire institution?
- What factors contribute to scalability?

3.5 Best Practices and Recommendations

Lessons Learned: Identify best practices and lessons learned.

- What strategies have yielded the most positive outcomes?
- What pitfalls should be avoided?

Recommendations for Improvement: Solicit recommendations for enhancing digital transformation efforts.

- How can the institution further enhance its digital ecosystem?
- What recommendations would you give to other institutions considering implementing sustainable digital transformation strategies??

The following guidelines are recommended by UNISA to ensure the safety of the researcher and participant(s):

- Do not proceed with the intended contact data collection visit or meeting if the researcher and/or participant is feeling unwell.
- Telephonic pre-screening before the visit is advised, as well as keeping a register of participants that were involved in face-to-face data collection activities.
- The researcher and members of the research team must also be screened before any human participant contact. Keep evidence of the screening data signed by a witness.

4. FINAL STAGE

In the final stage the interview is concluded by asking the participants if they would like to add anything (if applicable)

The participant will also be asked if they feel they need to speak to a professional counsellor as a result of perhaps reliving certain experiences that might have been discussed during the interviews.

Participants was referred to
……
……. should they feel they need counselling or further support.

Appendix D1: Interview schedule - MIS managers

Target Group: MIS Managers

Interview Format: Semi-structured (individual)

Estimated Duration: 45-60 minutes

Focus Areas: Data governance, digital systems, reporting, cybersecurity, integration, infrastructure

In this section the open-ended questions asked the participants:

A. **Background information**

- Name:
- Position/Title:
- Institution:
- Years of Experience in Higher Education:

Theme 1: Data-driven decision-making and analytics

1. How does your department support data-driven decision-making within the TVET college, and what types of analytics tools or platforms are used to support institutional planning and reporting?

Theme 2: System interoperability and integration

2. Can you describe the extent to which your college's various digital systems, for example, LMS, HR, finance, student information systems, are integrated? What challenges or opportunities have arisen from this integration?

Theme 3: Cybersecurity and data privacy policies

3. What cybersecurity protocols and data privacy policies are in place to protect sensitive institutional and student data, and how are these monitored and enforced?

Theme 4: Infrastructure for digital transformation

4. To what extent does the existing ICT infrastructure support the college's digital transformation goals, and what improvements are most urgently needed from your perspective?

Theme 5: Data governance and quality assurance

5. What systems or practices are in place to ensure data accuracy, consistency, and timeliness across institutional systems, and how is data quality monitored over time?

Theme 6: Technical Barriers to sustainable digital transformation (SDT)

6. What are the most significant technical or infrastructural barriers that limit progress toward sustainable digital transformation in your college, and how have you attempted to address these issues?

Theme 7: Staff capacity and digital skills

7. In your opinion, how well-equipped are staff and faculty to engage with institutional data systems, and what kind of training or support would enhance system usage and data literacy?

Theme 8: Strategic alignment and institutional support

8. How well do institutional digital transformation goals align with MIS priorities, and to what extent are MIS needs considered in strategic planning and budgeting?

Theme 9: Emerging Technologies and Future Readiness

9. How is your college preparing to adopt or scale emerging digital tools, for example, AI-based analytics, cloud systems, and what role does your department play in evaluating these technologies for future use?

Appendix D2: Interview schedule - ICT managers

Target Group: ICT Managers

Interview Format: Semi-structured (individual)

Estimated Duration: 45-60 minutes

Focus Areas: Infrastructure management, technical support, systems maintenance, cybersecurity, innovation enablement

In this section the open-ended questions asked the participants:

A. **Background Information**

- Name:
- Position/Title:
- Institution:
- Years of Experience in Higher Education:

Theme 1: Infrastructure adequacy and limitations

1. How would you describe the current state of the college's IT infrastructure in supporting digital learning and administration? What limitations have you encountered?

Theme 2: Device and Connectivity Availability

2. To what extent do educators and students have reliable access to devices and internet connectivity on campus and remotely? What gaps still exist?

Theme 3: Technical support and user training

3. What kinds of technical support services and digital training are currently offered to staff and students, and how effective are they in addressing user needs?

Theme 4: System maintenance and upgrades

4. How are digital systems and infrastructure maintained and updated? What challenges do you face in ensuring system reliability and uptime?

Theme 5: Data governance and quality assurance

5. How are IT resources allocated and prioritised within your institution, and what funding or policy mechanisms support long-term sustainability?

Theme 6: Helpdesk and user support strategies

6. What systems are in place for responding to user issues or IT incidents? How do you assess and improve the responsiveness of your support structures?

Theme 7: Innovation in it service delivery

7. Can you share examples of innovative IT service delivery models your department has adopted to improve efficiency or expand access to digital tools?

Theme 8: Digital tool selection and deployment

8. How are decisions made about adopting new digital tools or platforms, for example, LMS, collaboration tools? What role does the IT department play in their implementation and scaling?

Theme 9: Future Readiness and Strategic Planning

9. What strategies are in place to future-proof your IT systems against emerging technological demands or sustainability challenges?

Appendix D3: Interview schedule - Campus managers

Target Group: Campus Managers

Interview Format: Semi-structured (individual)

Estimated Duration: 45-60 minutes

Focus Areas: Leadership, governance, strategic alignment, budgeting, policy implementation

In this section the open-ended questions asked the participants:

A. **Background Information**

- Name:
- Position/Title:
- Institution:
- Years of Experience in Higher Education:

Theme 1: Leadership vision and strategic alignment

1. How would you describe your campus's strategic vision for digital transformation, and how is this vision communicated and aligned with broader institutional goals?

Theme 2: Governance processes and accountability

2. What governance structures or committees are in place to oversee digital transformation initiatives? How do they ensure transparency and accountability?

Theme 3: Policy development and compliance

3. To what extent are digital transformation policies clearly defined and implemented at your campus? What challenges have you encountered with compliance?

Theme 4: Resource allocation and budgeting

4. How are resources; financial, human, and technological, allocated to support digital initiatives at the campus level? Are these allocations adequate and sustainable?

Theme 5: Institutional culture and stakeholder buy-in

5. How would you describe the institutional culture regarding innovation and change? What strategies are used to engage staff and students in digital initiatives?

Theme 6: Stakeholder engagement and communication

6. What mechanisms exist for involving educators, IT personnel, and students in planning and evaluating digital transformation efforts?

Theme 7: Monitoring and evaluation of digital projects

7. How do you monitor and assess the progress and effectiveness of digital transformation initiatives? What key indicators or reporting methods are used?

Theme 8: Leadership challenges and capacity

8. What leadership challenges have you faced in driving digital transformation, and what additional support or capacity-building would be beneficial?

Theme 9: Sustainability Planning

9. What long-term strategies are in place to ensure that digital transformation remains sustainable and adaptable to changing needs at your campus?

Appendix D4: Focus group schedule Post-levels 2 and 3 lecturers

Target Group: Lecturers (Post-levels 2 and 3)

Interview Format: Semi-structured (Focus group)

Estimated Duration: 45-60 minutes

Focus Areas: Teaching and learning, digital integration, pedagogy, student outcomes

In this section the open-ended questions asked the participants:

A. **Background Information**

- Name:
- Position/Title:
- Institution:
- Years of Experience in Higher Education:

Theme 1: Integration of digital tools in teaching

1. How have you integrated digital tools into your curriculum delivery, and what has been the impact on your teaching practices?

Theme 2: Digital literacy and competence

2. How would you assess your own digital literacy, and what training or support have you received (or still require) to effectively use digital tools in the classroom?

Theme 3: Student engagement and outcomes

3. In what ways have digital technologies influenced student engagement, motivation, and academic performance in your modules?

Theme 4: Curriculum adaptation and pedagogical shift

4. What changes, if any, have you made to your curriculum or teaching methods due to the integration of digital technologies?

Theme 5: Challenges in Using Digital Tools

5. What are the main challenges you face in using digital tools for teaching and learning, and how have you attempted to overcome them?

Theme 6: Challenges in using digital tools

6. What kinds of professional development or peer support have been most useful for enhancing your digital teaching capabilities?

Theme 7: Student digital competency

7. How would you describe your students' readiness and ability to engage with digital learning resources, and what gaps have you observed?

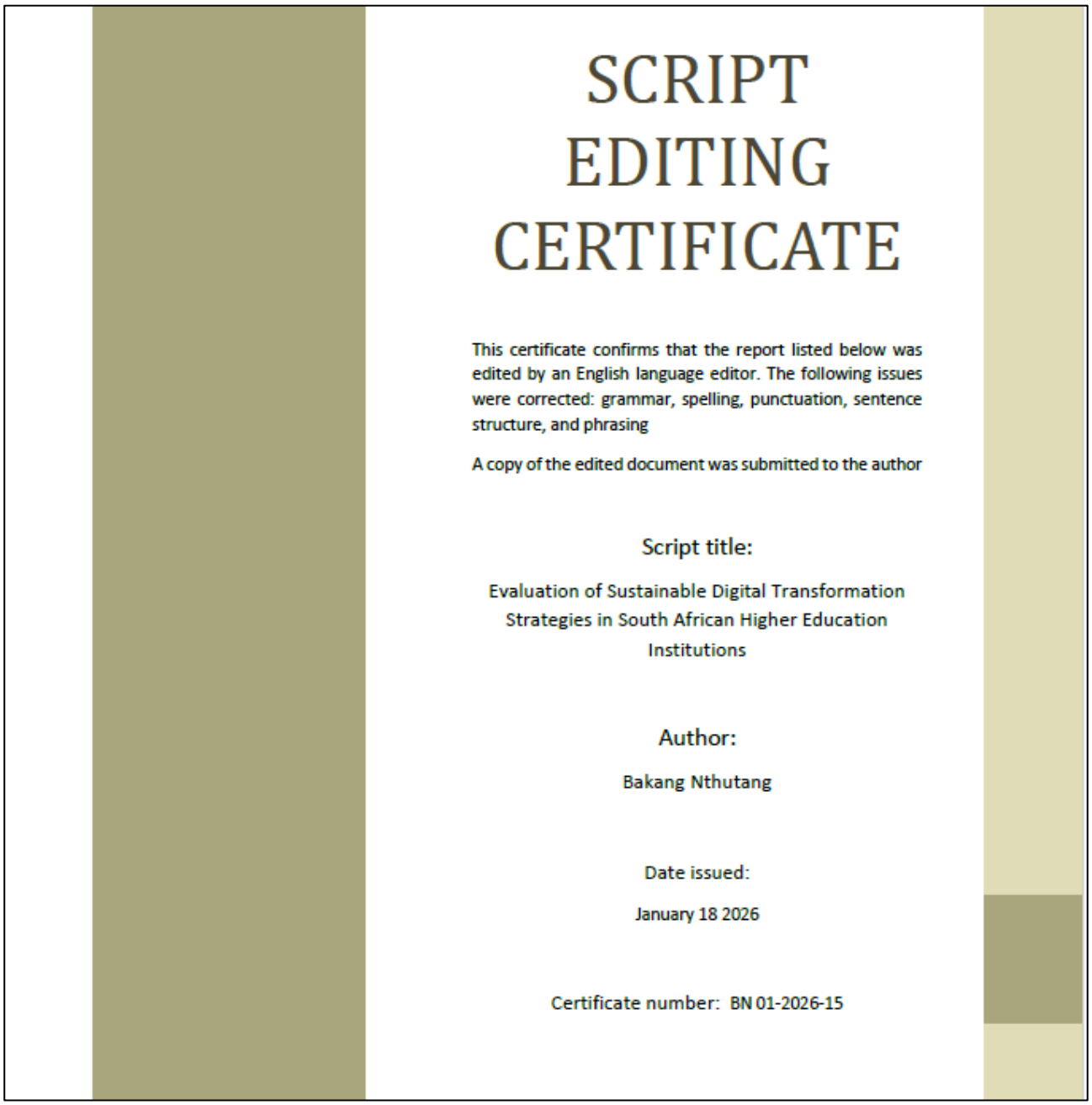
Theme 8: Access and infrastructure

8. How does access to devices, connectivity, and infrastructure affect your ability to deliver digitally supported teaching?

Theme 9: Recommendations for sustainable practice

9. Based on your experience, what recommendations would you make to ensure that the use of digital technologies in teaching is both effective and sustainable?

Appendix E: Confirmation of Editing



SCRIPT EDITING CERTIFICATE

This certificate confirms that the report listed below was edited by an English language editor. The following issues were corrected: grammar, spelling, punctuation, sentence structure, and phrasing

A copy of the edited document was submitted to the author

Script title:

Evaluation of Sustainable Digital Transformation Strategies in South African Higher Education Institutions

Author:

Bakang Nthutang

Date issued:

January 18 2026

Certificate number: BN 01-2026-15

Appendix F: Cover letter of an anonymous survey

Ethical clearance #: 3430

COVER LETTER TO AN ANONOMOUS SURVEY

Dear Prospective participant,

You are invited to participate in a survey conducted by Mr Bakang Nthutang under the supervision of Dr Mampilo Phahlane, the Director of the School of Computing, towards a PhD in Information Systems at the University of South Africa.

The survey you have received has been designed to assess how well South African Higher Education Institutions are adopting digital tools and practices that benefit the environment and the future. You were selected to participate in this survey because you are a member of the academic community who has been at the institution for over one year. You will not be eligible to complete the survey if you are younger than 18 years and are not a member of the academic community, or have not been at the institution for over one year. In completing this survey, you agree that the information you provide may be used for research purposes, including dissemination through peer-reviewed publications and conference proceedings.

It is anticipated that the information we gain from this survey will help us to develop a model that serves as a foundation for designers and other professionals to assess and evaluate the sustainability of DT Strategies within South African public TVET colleges. You are, however, under no obligation to complete the survey, and you can withdraw from the study prior to submitting the survey. The survey is designed to be anonymous, meaning we will have no way to connect the information you provide to you personally. Consequently, participating in this study is voluntary, and you are not obligated to consent to participation. Participants are not expected to face any risks by participating in this study. However, should you have any discomfort, the contact details of the researcher and supervisor are provided, and you may withdraw as a respondent from the study if you have not submitted the questionnaire. Confidentiality was maintained at all levels. If you choose to participate in this survey it will take up no more than 20 minutes of your time. You will not benefit from your participation as an individual, however, it is envisioned that the findings of this study will help

us to develop a theoretical framework that encapsulates the holistic impact of digital transformation on TVET colleges, considering their unique functions and characteristics. Serving as a foundation for designers and other professionals to assess and evaluate the sustainability of DT strategies within South African public TVET colleges. We do not foresee any negative consequences for you in completing the survey. The researcher undertakes to keep any information provided herein confidential, not to disclose it, and to report the findings from the perspective of the participating group, not from an individual's perspective.

The records will be kept for a minimum period of five years for audit purposes, after which they will be permanently destroyed. Hard copies will be shredded, and electronic versions will be permanently deleted from the computer's hard drive. You will not be reimbursed or receive any incentives for your participation in the survey.

The research was reviewed and approved by the School of Computing Research Ethics Committee. The primary researcher, Bakang Nthutang, can be contacted during office hours at 44594925@mylife.unisa.ac.za, 011 670 9132. The study leader, Dr Mampilo Phahlane, can be contacted during office hours at phahlmm@unisa.ac.za, 011 670 9176. Should you have any questions regarding the ethical aspects of the study, you can contact the chairperson of the Dr. Danie Bischoff, Dbischof@unisa.ac.za. Alternatively, you can report any serious unethical behaviour at the University's Toll Free Hotline 0800 86 96 93.

Appendix G: Peer-reviewed publications from the thesis

sustainability

MDPI

Systematic Review

Sustainability-Aligned Digital Risks in South African Higher Education: A Systematic Review (2019–2025)

Bakang Nthutang *, Mampilo Phahlane and Lario Malungana

Department of Information Systems, College of Science, Engineering and Technology, University of South Africa, Pretoria 0003, South Africa; phahlmm@unisa.ac.za (M.P.) emaluril1@unisa.ac.za (L.M.)
* Correspondence: nthutb@unisa.ac.za

Abstract

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.

Keywords: digital divide; digital transformation; higher education; sustainability; South Africa; systematic review

Academic Editor: Grigorios L. Kyriakopoulos

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Revised: 16 December 2025
Accepted: 24 December 2025
Published: date

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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. The gaps in policy and practice are identified. The paper supports policy development, institutional planning and the advancement of sustainability-aligned digitalisation in South African higher education. It contributes to the understanding of how digital transformation (DT) intersects with sustainability in a developing context, offering insight into equitable and resilient HE strategies. The paper sought to answer the *What sustainable digital risks have emerged for SA HEIs between 2019 and 2025?* research question. This section reviews key concepts of the phenomenon.

Article

Emerging Trends in Sustainable Digital Transformation Strategies in Higher Education Institutions: A Systematic Review

Bakang Nthutang [1,*], Mampilo Phahlane [1,*] and Lario Malungana [1,*]

[1] Department of Information Systems, College of Science, Engineering and Technology, University of South Africa, Johannesburg, South Africa

* Correspondence: nthutb@unisa.ac.za (B.N.); phahlmm@unisa.ac.za (M.P.); emalunl1@unisa.ac.za (L.M.)

Abstract: The technological revolution has had a profound impact on environmental and social issues globally. On the positive side, it has fostered advancements in renewable energy technologies, healthcare improvements, and enhanced communication tools. Conversely, it has also led to negative consequences, such as increased industrialisation and pollution, a widening digital divide, and adverse social effects stemming from automation. In higher education institutions, there is a theoretical gap in systematic reviews of the integration of digital transformation into sustainability. The review presented here was conducted with the intention of reducing this gap through an exploration of how digital transformation improves sustainability in higher education institutions, based on the identification of emerging trends and best practices for effective strategies. Using the PRISMA guidelines, the researchers conducted a comprehensive search of the Scopus database, which yielded 1,686 articles published in academic journals between 2019 and 2024. The findings reveal a widespread awareness of digital technology integration, but equally reveal a lack of consensus on sustainable integration strategies. Furthermore, the results demonstrate that educational achievements can be enhanced through tools and methodologies that align with the United Nations Sustainable Development Goals. Three primary domains were identified: sustainability capabilities made possible by digital transformation, innovative sustainable approaches, and the conceptualisation of sustainability in higher education. The incorporation of digital tools, such as AI chatbots, enables institutions to foster innovation and achieve sustainability objectives, thus transforming teaching and learning approaches. The review conducted contributes significantly to understanding the role of digital transformation in promoting a sustainable and digitally enabled future in higher education.

Keywords: sustainability; sustainable development; digital transformation; higher education; technology; innovation

Citation: To be added by editorial staff during production.

Academic Editor: First name Last-name

1. Introduction

Rapid advances in digital technologies have led to a new era of unprecedented change, transforming numerous aspects of life today, including approaches to sustainable