Operationalizing the Metaverse in South African Higher Education: A Readiness Assessment and Strategic Framework

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Abstract

The metaverse has emerged as a transformative digital innovation with the potential to reshape higher education and Technical and Vocational Education and Training (TVET) through immersive, interactive, and experiential learning environments. Building on the foundational work of [1], which identified the metaverse as a potential solution to study space shortages in South African higher education institutions, this study investigates institutional readiness, stakeholder perceptions, and strategic pathways for operationalising metaverse technologies within South African Higher Educational Institutions (HEIs), especially TVET colleges. The study is situated within the broader national agenda to expand post-school education and training, particularly the goal of increasing TVET enrolments to approximately 2.5 million students by 2030 [2, 3]. Given growing enrolments, infrastructure constraints, and the need for innovative approaches to skills development, the metaverse presents opportunities to enhance access, experiential learning, and vocational training while reducing pressure on physical facilities. A qualitative research design was employed, with data collected through semi-structured interviews involving academic leaders, digital transformation specialists, educators, and policy advisors. Data were analysed using [4] thematic analysis framework. Five key themes emerged: institutional infrastructure readiness, digital competencies and capacity building, policy and governance readiness, implementation challenges and risks, and opportunities associated with metaverse adoption. The findings reveal growing institutional interest in immersive technologies and evidence of emerging digital readiness; however, significant challenges remain, including infrastructure disparities, inadequate digital competencies, limited policy frameworks, funding constraints, cybersecurity concerns, and persistent inequalities across institutions. Participants nevertheless highlighted the metaverse's potential to enhance experiential learning, simulation-based training, student engagement, and access to vocational education. In response to these findings, the study proposes a Metaverse Readiness and Implementation Framework (MRIF) to guide institutions through readiness assessment, governance development, stakeholder engagement, capacity building, phased implementation, and continuous evaluation. The framework provides a contextually relevant roadmap for supporting sustainable, inclusive, and strategically governed metaverse adoption within South African higher education especially TVET colleges.

Keywords: *Metaverse, Virtual Study Spaces, Higher Education, TVET colleges, Digital Learning, Virtual Reality, Education Technology*

1. Introduction

The global higher education sector is experiencing significant transformation as institutions respond to the rapid technological changes associated with the Fourth Industrial Revolution (4IR). Emerging digital technologies such as artificial intelligence (AI), virtual reality (VR), augmented reality (AR), blockchain, and extended reality (XR) are reshaping teaching, learning, research, and institutional operations [5, 6]. Within this evolving digital ecosystem, the metaverse has emerged as a transformative innovation with the potential to redefine educational delivery and student engagement in higher education. The metaverse refers to a persistent, immersive, and interconnected virtual environment in which users interact through digital avatars in real time using advanced immersive technologies [7, 8]. In educational contexts, the metaverse enables experiential, collaborative, and interactive learning beyond the limitations of physical classrooms. Through virtual laboratories, simulations, digital campuses, and immersive collaborative spaces, the metaverse offers opportunities to enhance student engagement, improve accessibility, and support innovative pedagogical practices aligned with constructivist and connectivist approaches to learning [9].

Globally, universities are increasingly exploring metaverse applications to support flexible and technologically enhanced learning environments. Institutions in developed countries have begun implementing immersive learning platforms for disciplines such as engineering, medicine, architecture, and teacher education, where simulation-based learning can improve practical competence and student participation [6]. The metaverse is further viewed as an important component of digital transformation strategies aimed at improving institutional competitiveness, innovation, and global collaboration in higher education. The need for innovative approaches to educational delivery is further amplified by South Africa's national skills development agenda. The National Development Plan (NDP) 2030 and the White Paper for Post-School Education and Training position TVET colleges as critical institutions for addressing unemployment, poverty, and economic growth through skills development [2, 3]. To achieve these objectives, government has set ambitious enrolment expansion targets for the TVET sector, with long-term plans aimed at accommodating approximately 2.5 million students. However, expanding enrolments at this scale presents significant challenges relating to infrastructure, equipment, workshop space, and lecturer capacity. Emerging technologies such as the metaverse may provide innovative opportunities to support expanded access and quality vocational training through immersive and scalable learning environments. Existing studies suggest that the metaverse may provide innovative solutions to challenges such as overcrowded campuses, limited physical infrastructure, and restricted access to practical learning environments [1].

Despite these opportunities, the adoption of metaverse technologies remains uneven across different socio-economic and institutional contexts. In developing countries such as South Africa, higher education institutions continue to face structural and systemic barriers that hinder advanced digital transformation initiatives. These challenges include inadequate digital infrastructure, unstable internet connectivity, electricity disruptions, limited financial resources, insufficient technical expertise, and persistent inequalities between historically advantaged and disadvantaged institutions [10, 11]. Such disparities significantly affect institutional capacity to adopt sophisticated immersive technologies and may deepen existing educational inequalities if not adequately addressed. The COVID-19 pandemic further exposed the vulnerability of South African higher education institutions especially TVET colleges regarding digital readiness and technology integration. Although some institutions successfully transitioned to online and blended learning models, many institutions experienced significant challenges related to infrastructure limitations, staff preparedness, student access to digital devices, and affordability of internet connectivity [12, 13]. The pandemic highlighted the persistent digital divide within South African higher education especially TVET colleges, particularly among students from rural and economically disadvantaged communities, thereby raising concerns about equitable access to emerging technologies such as the metaverse [14].

Furthermore, despite the increasing global interest in metaverse technologies as transformative tools for education, there is limited empirical evidence regarding the readiness of South African post-school institutions, particularly TVET colleges, to adopt and implement immersive learning environments. TVET colleges face unique challenges associated with infrastructure constraints, unequal access to digital technologies, lecturer digital competencies, and the need to deliver practice-oriented learning experiences that mirror real workplace environments. Although immersive technologies may offer innovative solutions for vocational training through virtual simulations, laboratories, and workplace-based learning experiences, little is known about the institutional, technological, and human-capacity requirements necessary for successful implementation. Consequently, the absence of context-specific readiness frameworks creates uncertainty regarding the feasibility, sustainability, and equity implications of metaverse adoption within South African TVET colleges and the broader higher education sector. The study aims to investigate institutional readiness, stakeholder perceptions, and strategic pathways for operationalising metaverse technologies within South African HEIs, especially TVET colleges.

2. Review of Related Literature

2.1. Theoretical and Conceptual Foundations

The integration of metaverse technologies in higher education is grounded in several technology adoption and digital learning frameworks. Diffusion of Innovation Theory posits that technological adoption depends on perceived usefulness, compatibility, complexity, and institutional support [15]. Similarly, the Technology Acceptance Model (TAM) emphasizes that perceived usefulness and ease of use directly determine user willingness to adopt new tools [16]. In the metaverse context, educators and

students embrace immersive platforms when they perceive them as catalysts for teaching effectiveness and enhanced learning. Pedagogically, constructivist and connectivist learning theories support this immersion. Constructivism states that learners actively build knowledge through interactive experiences, while connectivism emphasizes digital networking and collaborative learning [17]. The metaverse merges these views by offering highly interactive, experiential, and collaborative virtual environments.

2.2. Digital Transformation in Higher Education

Digital transformation is a global strategic priority driven by the Fourth Industrial Revolution (4IR), which has integrated artificial intelligence, cloud computing, virtual reality, and learning management systems into universities to improve access and quality [5]. This shift demands deep organizational change, pedagogical innovation, and process restructuring [18]. In South Africa, the COVID-19 pandemic forced a rapid transition to online and blended models [12], but exposed severe institutional inequalities in digital readiness, infrastructure, and staff preparedness between historically advantaged and disadvantaged universities [19]. Today, local digital transformation remains constrained by inadequate funding, unstable internet access, rolling power outages, and limited digital competencies among students and academics [10], barriers that heavily impede metaverse adoption.

2.3. *Metaverse and Immersive Learning*

The metaverse is an interconnected, real-time virtual ecosystem where users interact via avatars through a blend of virtual/augmented reality, artificial intelligence, and blockchain [7, 8]. Educationally, it facilitates boundaryless, simulation-based learning through virtual laboratories and collaborative projects [6]. These immersive environments boost student engagement, motivation, and knowledge retention via active participation [9]. Furthermore, virtual campuses can help institutions bypass physical infrastructure limits and overcrowding, expanding access to practical, lab-based disciplines [1]. However, scholars note that deployment is hindered by high financial costs, cybersecurity threats, privacy issues, and complex ethical governance [20].

2.4. Metaverse Applications in TVET Education

Technology-enhanced learning is critical for the South African Technical and Vocational Education and Training (TVET) sector, where curricula demand hands-on, occupational competencies. The metaverse offers virtual workshops and industry environments where students can practice technical skills safely and repeatedly, overcoming physical workshop limitations. This immersive framework directly fosters the technical and employability skills required for Industry 4.0 [6, 8]. The National Development Plan (NDP) 2030 positions TVET colleges as central to tackling youth unemployment, while the White Paper for Post-School Education and Training targets massive growth to 2.5 million [2, 3]. Expanding via brick-and-mortar infrastructure is financially impossible. Metaverse technologies offer a viable alternative pathway to scale training capacity, reach remote learners, and offer flexible delivery models [1]. This potential, however, depends heavily on whether institutions possess the necessary infrastructure, policy frameworks, and human capacity.

2.5. *Institutional Readiness for Technology Integration*

Institutional readiness is the baseline technological, financial, human, and organizational capacity required to successfully implement innovation. It encompasses digital infrastructure, clear policy frameworks, leadership commitment, staff competencies, and supportive organizational culture [21]). Institutions with strong leadership and robust digital policies deploy emerging technologies effectively [22]. Conversely, low readiness sparks user resistance and widens educational inequalities. In South Africa, readiness remains highly uneven; rural and historically disadvantaged institutions face persistent bandwidth limitations, infrastructure deficits, and severe funding gaps [11].

2.6. *Challenges of Digital Transformation in South African Higher Education*

Digital transformation in South African universities is severely impeded by systemic socio-economic and technical barriers. Chief among these is the persistent digital divide, which restricts equitable access to

devices, reliable internet, and online learning platforms for students from low-income or rural backgrounds [14]. Operational hurdles include rolling power outages (load shedding), deficient broadband infrastructure, legacy technological hardware, and under-resourced ICT support desks ([23]. Furthermore, widespread institutional financial constraints restrict high-end investments in immersive tech and academic training. These infrastructural issues are compounded by human barriers, notably academic resistance to change, gaps in digital literacy, and missing institutional policy frameworks [24]. Consequently, adopting advanced systems like the metaverse demands comprehensive institutional restructuring rather than simple technological procurement.

2.7. Opportunities and Risks of Immersive Technologies

Immersive platforms offer powerful avenues to elevate higher education by hosting experiential, simulation-driven learning that sharpens 21st-century competencies like creative problem-solving and deep digital literacy [25]. Conversely, deploying these systems introduces profound ethical, operational, and psychological risks. Key vulnerabilities include data privacy breaches, cybersecurity threats, and psychological strain from extended virtual immersion [20]. Furthermore, the steep capital required for advanced hardware, software licensing, and specialized staff training presents a major barrier for budget-constrained universities. If unmitigated, these costs risk deepening student exclusion. Successful metaverse integration therefore hinges on rigorous strategic planning, ethical policy frameworks, stakeholder alignment, and proactive equity strategies.

3. Research Methodology

This study employed a qualitative research approach grounded in the interpretivist paradigm to explore institutional readiness for metaverse integration in South African higher education institutions [26]. An exploratory case study design was adopted to gain in-depth insights into stakeholders' perceptions, experiences, and preparedness regarding immersive technologies in teaching and learning [26].

3.1. Participant Selection

A purposive sampling technique was used to select 8 participants with relevant knowledge and experience in digital transformation and educational technology integration. Using purposive sampling enabled the researcher to obtain rich and contextually relevant data from participants directly involved in institutional technology adoption processes [26]. The selected participants included academic staff, ICT personnel, institutional managers, and e-learning coordinators involved in digital transformation initiatives within HEIs.

3.2. Profiles of Participants

The eight participants were purposively sampled to provide a comprehensive, multi-level overview of the post-school education and training sector, spanning national policy, institutional management, and frontline execution.
National Policy Level: Mr Sello Sethusha (DHET Director of Lecturer Development and Support) and Dr Moyo Mtheto (DHET Acting Director of International Scholarships) were selected to provide critical insights into national capacity-building frameworks, international education partnerships, and the broader policy landscape governing metaverse adoption. Institutional Leadership & eLearning Strategy: Ms Zandile Nkabinde (Deputy Principal, Majuba TVET College) was chosen to offer a strategic perspective on institutional management, focusing on resource allocation, operational infrastructure constraints, and staff readiness. Complementing this, Ms Phumzile Mthiyane (Deputy Chief Education Specialist, eLearning Directorate) was selected for her specialized expertise in designing and integrating digital learning policies. Frontline Classroom Execution: Four TVET college lecturers; Ms Khathu Mangaladzi (CJC TVET College), Mr Dlamini (Majuba TVET College), Ms Precious, and Ms T.G. Ndou (both Vhembe TVET College), were selected to capture the practical realities of daily teaching, user-level experiences with digital tools, and the pedagogical shifts needed for immersive learning.

3.3. Data Collection

Data was collected through semi-structured interviews conducted either face-to-face or via online platforms such as Microsoft Teams and Zoom. The interviews focused on institutional infrastructure, digital competencies, policy readiness, implementation challenges, and opportunities associated with metaverse adoption.

3.4. Data Analysis

Data was analysed using thematic analysis following the six-phase framework developed by [4], enabling the identification and interpretation of recurring themes and patterns within the data. The process included familiarization with data, generating initial codes, generating initial themes reviewing potential themes, defining and naming themes, and producing the report. To ensure trustworthiness, the study applied the principles of credibility, dependability, confirmability, and transferability as proposed by [27]. Ethical considerations, including informed consent, confidentiality, anonymity, and voluntary participation, were observed throughout the study.

4. Findings

Using [4] six-phase thematic analysis framework, five overarching themes emerged from the interview data: (1) Institutional Infrastructure Readiness, (2) Digital Competencies and Capacity Building, (3) Policy and Governance Readiness, (4) Implementation Challenges and Risks, and (5) Opportunities and Future Potential of the Metaverse. These themes provide insights into the readiness of South African higher education institutions and TVET colleges to adopt metaverse technologies and inform the development of a strategic framework for implementation.

4.1. Institutional Infrastructure Readiness

Participants acknowledged significant progress in digital transformation, particularly following the COVID-19 pandemic, through the adoption of Learning Management Systems (LMSs), online learning platforms, and blended learning approaches. However, readiness was found to be uneven across institutions, with disparities in infrastructure, connectivity, and access to digital resources remaining a major concern.

One participant highlighted both the progress made and the existing challenges:

“TVET colleges have made massive progress by adopting LMSs and online teaching platforms, but there are still limitations because of inadequate bandwidth, outdated computers, insufficient software licences and shortages of modern devices.”

Similarly, a senior DHET official emphasised the inequalities that continue to characterise the higher education landscape:

“We have urban universities, rural universities, historically white universities and historically black universities… some rural universities did not have the basic equipment, basic internet connection and basic computers.”

4.2. Digital Competencies and Capacity Building

The second theme focused on the digital competencies required for successful metaverse implementation. Participants consistently emphasised educator training, technical support, and continuous professional development as critical enablers of adoption.

As one participant explained:

“The educators would require hands-on technical training, instructional design support, continuous professional development, mentoring and communities of practice, technical support services and clearly defined policies.”

Participants also recognised that students may adapt more quickly to immersive technologies than educators due to greater familiarity with digital environments:

“Students may embrace immersive technologies because it aligns with their experiences… but some educators have cyberphobia and fear of technology.”

4.3. Policy and Governance Readiness

Policy and governance readiness emerged as one of the weakest dimensions of institutional preparedness. Although institutions have increasingly embraced digital technologies, participants reported the absence of comprehensive policies to guide the implementation and governance of immersive technologies.

One participant stated:

"I don't think we have policies in our institutions that guide us about how to utilise technology and how to manage technology."

Another participant highlighted the broader governance responsibilities associated with metaverse adoption:

"The issue is what support must policymakers provide to universities. That is funding… and also issues of ethics as well because embedded in the metaverse are issues of AI."

Participants argued that policy frameworks should address ethical governance, cybersecurity, accessibility, artificial intelligence, and sustainable funding.

4.4. Implementation Challenges and Risks

Participants identified several challenges that could hinder the adoption of metaverse technologies, including financial constraints, inadequate infrastructure, digital inequality, cybersecurity concerns, and resistance to change.

One participant summarised these concerns succinctly:

"Financial constraints, inadequate digital infrastructure, inequality in access to devices, cybersecurity and data privacy concerns, lack of policies and resistance to change."

Participants were particularly concerned about the potential for metaverse implementation to exacerbate existing inequalities within the higher education sector:

"The institutions should be very careful that they don't widen the existing inequalities… equity should be embedded into every stage of implementation. Nobody should be left behind."

Without targeted interventions, metaverse adoption may reinforce existing inequalities rather than address them.

4.5. Opportunities and Future Potential of the Metaverse

Despite these challenges, participants overwhelmingly viewed the metaverse as a transformative educational innovation capable of enhancing experiential learning, improving access, and supporting practical skills development.

A tourism lecturer illustrated the educational possibilities offered by immersive technologies:

"I can take my students to Table Mountain while I'm in Johannesburg… students are going to be provided with simulated environments and engage with experiential learning."

Another participant highlighted the value of simulations for practical learning:

"Visual simulations will provide students with realistic learning experiences that may otherwise be expensive or inaccessible."

Participants viewed the metaverse as particularly beneficial for engineering, tourism, hospitality, logistics, aviation, and vocational education programmes that require practical and experiential learning opportunities.

5. Discussion

The findings demonstrate that institutional readiness for immersive technology in a developing country context cannot be viewed as a purely technological phenomenon. Instead, it is a complex sociotechnical ecosystem where infrastructure, digital literacies, institutional governance, and socio-economic history collide.

A critical finding of this study is the persistent unevenness of institutional infrastructure readiness, which is starkly divided along historical lines (urban vs. rural and historically white vs. historically black institutions). While the post-COVID-19 era accelerated the baseline adoption of Learning Management Systems (LMSs) and blended modalities across South Africa, this study shows that transitioning to the metaverse requires an entirely different order of technological capital. The presence of basic internet and outdated hardware does not equate to metaverse readiness, which demands massive bandwidth,

low-latency connectivity, high-end graphic processing power, and specialized peripheral hardware (e.g., VR headsets).

This infrastructure disparity strongly echoes the warnings of [11] and [10], who argue that blanket digital transformation policies frequently fail because they ignore underlying institutional inequalities. Within the broader South African discourse, these results add an immersive-technology layer to the structural digital divide documented by [14]. If South African higher education blindly deploys metaverse spaces without targeted capitalization, it risks cementing a two-tier educational system: a technologically enriched immersive experience for well-resourced urban universities, and a text-based, resource-constrained experience for rural and TVET campuses. Therefore, infrastructure readiness must be conceptualized not just as "having technology," but as achieving equity of access to specialized technical architectures.

The findings indicate that technological infrastructure is entirely inert without a corresponding upgrade in human capability. The data revealed a stark contrast between a highly digitally fluent student body and an instructional workforce constrained by technical limitations and, in some cases, "cyberphobia." This dynamic can be directly interpreted through the lens of [16] Technology Acceptance Model (TAM). According to TAM, a user's intention to adopt a system is driven by its Perceived Usefulness (PU) and Perceived Ease of Use (PEOU). While the educational utility (PU) of the metaverse is widely acknowledged, its perceived ease of use among educators remains low due to a lack of instructional design support and hands-on technical training.

Furthermore, this human capital gap illustrates the structural bottlenecks predicted by [15] Diffusion of Innovations Theory. For an innovation to diffuse successfully through an organization, the social system must provide clear compatibility and observability. The findings highlight that South African institutions currently lack the organizational support systems needed to transition educators from "laggards" or "late majorities" into active adopters. This underscores that human capital development cannot be an afterthought; continuous professional development must run parallel to any hardware procurement.

Perhaps the most vulnerable dimension of readiness identified is the systemic absence of policy and governance frameworks tailored to immersive environments. While institutional policies have slowly adapted to traditional online learning, they are completely unequipped to handle the unique ethical, legal, and operational complexities of the metaverse. This policy vacuum aligns with observations by [21] and [22], who assert that institutional leadership and agile governance are the primary gatekeepers of sustainable digital transformation. Implementing the metaverse without predefined regulatory guardrails poses catastrophic risks regarding student safety, identity theft, and institutional liability. Furthermore, because the metaverse blurs geographical and physical boundaries, it creates complex questions around digital rights management and algorithmic bias. The findings imply that state bodies, such as the Department of Higher Education and Training (DHET), alongside institutional councils, must proactively move away from reactive policymaking and instead co-design proactive, ethically grounded governance frameworks that explicitly address immersive spaces.

When evaluating the data holistically, a profound paradox emerges between the identified risks (Theme 4) and the perceived opportunities (Theme 5) of the metaverse. On one hand, the metaverse introduces extreme financial strains onto already burdened public budgets and risks worsening the digital divide [24]. On the other hand, it offers unprecedented pedagogical opportunities for experiential, simulated, and collaborative learning that could democratize access to expensive physical training.

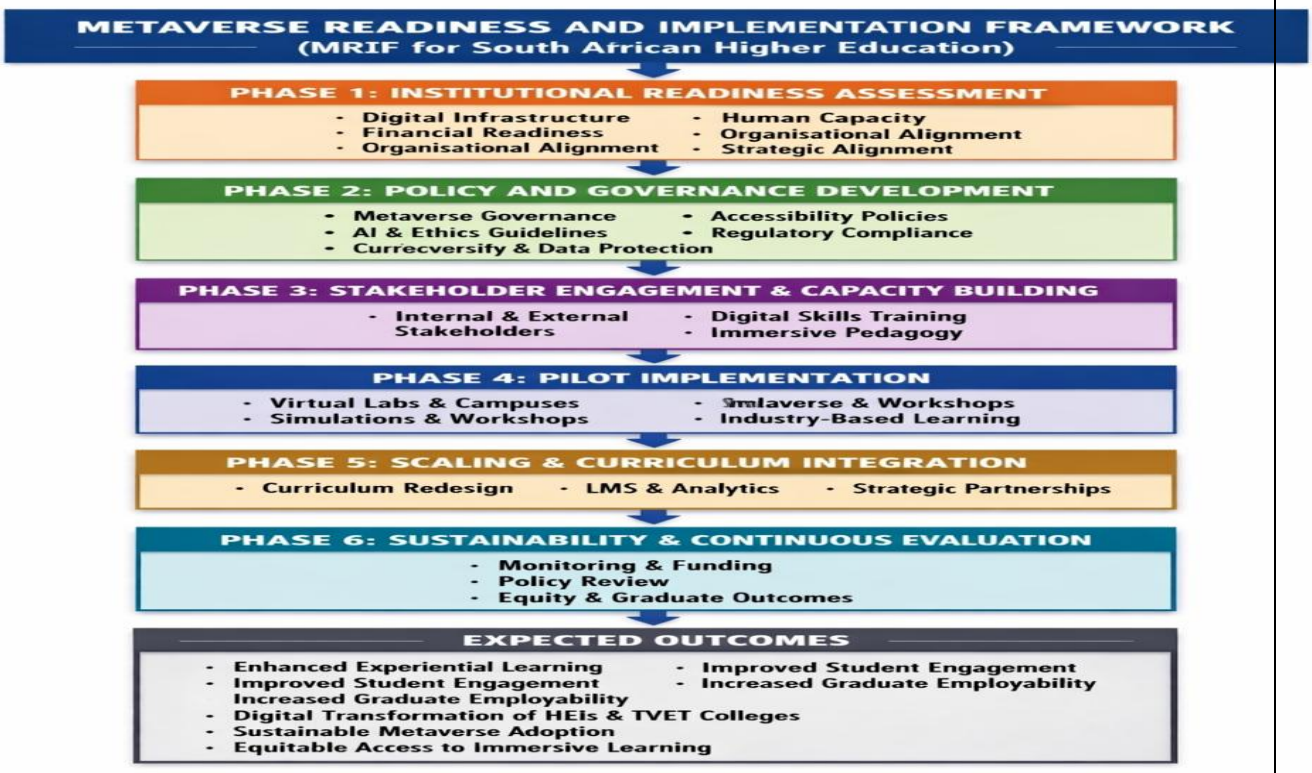
This pedagogical potential is highly consistent with constructivist and connectivist learning theories [17], which position learning as an active, networked process of generating meaning through experience. In disciplines that require expensive or high-risk physical infrastructure the metaverse offers an elegant solution to resource scarcity. As argued by [8], [9], and [6], high-fidelity virtual simulations allow students to bridge the gap between theory and practice safely and iteratively. The core implication is that the metaverse should not be pursued as a novelty or a generic replacement for traditional lectures; rather, its implementation must be highly strategic, targeting specific spatial, practical, and experiential learning modules where virtual simulation provides a clear, cost-effective educational advantage over physical infrastructure.

6. Proposed Framework

The Proposed Strategic Framework for Operationalising the Metaverse in South African Higher Education and TVET Colleges in **Figure 1** below provides a structured roadmap for institutions to assess readiness, implement immersive technologies, and sustain innovation in teaching and learning.

Grounded in Constructivism, Connectivism, the Technology Acceptance Model, and Diffusion of Innovation Theory, the framework integrates six sequential phases which are institutional readiness and policy development to stakeholder engagement, pilot implementation, scaling, and sustainability. Each phase aligns technological adoption with human capacity, governance, pedagogy, and strategic vision, ensuring that metaverse integration advances equity, inclusivity, and digital transformation. Ultimately, the framework empowers universities and TVET colleges to transition toward experiential, data-driven, and future-ready education ecosystems.

Fig. 1. Proposed Metaverse Framework



Source: Researchers Own Compilation

7. Conclusion

This study found that South African higher education institutions and TVET colleges demonstrate emerging readiness for metaverse adoption, evidenced by the increasing use of digital learning platforms, blended learning approaches, and collaborative initiatives aimed at enhancing teaching and learning. However, institutional readiness remains uneven due to infrastructure disparities, limited digital competencies, inadequate policy and governance frameworks, funding constraints, and persistent inequalities across the sector. While participants expressed strong optimism regarding the potential of immersive technologies to enhance experiential learning, student engagement, practical skills development, and access to education, they also highlighted significant challenges related to digital inclusion, cybersecurity, change management, and sustainability. The findings suggest that successful metaverse integration requires a holistic and coordinated approach that aligns technological infrastructure, human capacity development, governance mechanisms, stakeholder engagement, and equitable access strategies. In response to these findings, the study developed the Metaverse

Readiness and Implementation Framework (MRIF), which provides a context-specific roadmap to guide institutions through the stages of readiness assessment, policy development, capacity building, implementation, scaling, and continuous evaluation. The study therefore concludes that metaverse adoption is both feasible and desirable within the South African higher education and TVET sectors, provided it is implemented through a phased, inclusive, and strategically governed process that promotes sustainability, innovation, and educational equity.

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