

Stakeholder perceptions and the impact of the Fourth Industrial Revolution in South African TVET colleges: A qualitative study

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Abstract. This qualitative study examines the integration of Fourth Industrial Revolution (4IR) technologies in South African technical and vocational education and training (TVET) colleges, using the technology acceptance model (TAM) as a guiding framework. Data were collected through in-depth interviews and focus group discussions with 50 participants, including campus managers (10%), educators (50%), and students (40%) across five TVET campuses. Thematic analysis, facilitated by NVivo 12, identified patterns and themes related to adoption, challenges, and institutional responses. Findings indicate that 4IR technologies can enhance access to education, improve graduate employability, and support personalised learning. However, persistent barriers, such as infrastructure deficits, limited digital literacy, outdated curricula, resistance to technological change, and concerns over job displacement, impede effective integration. Stakeholders' acceptance of technology was influenced by perceptions of usefulness and ease of use, while social influence and facilitating conditions shaped confidence and engagement, reflecting TAM and UTAUT (unified theory of acceptance and use of technology) constructs. The study emphasises the significance of institutional readiness, equitable access, and ongoing professional development in fostering successful 4IR adoption. Policy and practice implications include revising curricula to align with 4IR competencies, expanding digital infrastructure, and fostering faculty capacity to integrate technology into pedagogical strategies.

Keywords: youth empowerment, skilled labour, Fourth Industrial Revolution, digital divide, curriculum development

1. Introduction

The Fourth Industrial Revolution (4IR), characterised by rapid advances in artificial intelligence, automation, and data technologies, is reshaping education and employment globally [11]. For South Africa, where youth unemployment, digital inequality, and persistent skills mismatches undermine labour market readiness, this transformation is especially urgent [6, 16]. Technical and vocational education and training (TVET) colleges, which serve large numbers of students from rural and peri-urban communities, are well-positioned to bridge these divides. However, outdated curricula, weak infrastructure, and limited digital capacity among educators continue to constrain their effectiveness. While research on 4IR in education is expanding, it remains disproportionately focused on universities, sidelining vocational institutions.

This neglect obscures the distinctive challenges TVET colleges face, particularly in underserved regions. This study addresses the gap by exploring how students, educators, and campus managers in South African TVET colleges perceive and experience the adoption of 4IR. Using the technology acceptance model (TAM) and the unified theory of acceptance and use of technology (UTAUT), it examines how perceived

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usefulness, ease of use, social influence, and institutional support shape technology integration [19].

1.1. Background

South Africa's TVET sector plays a critical role in addressing socio-economic challenges such as youth unemployment, poverty, and inequality [6]. Although reforms, such as the Continuing Education and Training Act [8], sought to modernise the sector, persistent weaknesses endure, including underqualified staff, outdated infrastructure, and curricula poorly aligned with labour market needs. The demands of the 4IR magnify these deficits, particularly in rural and under-resourced colleges. Unlike conventional training, 4IR requires innovation-oriented competencies such as creativity, problem-solving, and digital fluency [9].

However, limited staff training, unreliable internet, and inadequate infrastructure remain barriers to building these skills [18]. Policy frameworks emphasise entrepreneurship, curriculum renewal, and industry partnerships as drivers of transformation. However, implementation is uneven, leaving many TVET institutions unprepared for digital integration. This deepens inequalities between urban and rural campuses.

Nkangala TVET College in Mpumalanga exemplifies these realities. Serving both rural and urban communities, it illustrates uneven readiness: some campuses have invested in computer labs and learning management systems, while others lack even basic infrastructure. Its diversity makes Nkangala an instructive case for examining both opportunities and constraints in advancing vocational transformation [17].

1.2. Rationale

Globally, 4IR technologies are reshaping education and labour markets. In South Africa, these dynamics intersect with systemic inequalities, positioning TVET colleges as central to bridging the digital divide and enabling inclusive economic participation [16]. However, structural barriers, including outdated curricula, underqualified staff, and inadequate infrastructure, continue to limit their transformative potential, particularly in rural and semi-urban contexts.

Although the scholarship on 4IR in education is growing, the TVET sector remains underexplored. Most studies focus on universities and national strategies, neglecting the lived experiences of vocational educators and students who face digital exclusion and uneven institutional support. This study responds to that gap by investigating stakeholder perceptions of 4IR adoption at Nkangala TVET College. Drawing on TAM and UTAUT, it examines how perceptions of usefulness, ease of use, social influence, and institutional support influence technology adoption.

Three interrelated objectives anchoring this study:

1. To assess stakeholder perceptions (educators, students, and managers) of 4IR adoption, using TAM and UTAUT constructs.
2. To identify benefits and barriers to integration, including employability gains, innovation, skills displacement, and infrastructural deficits.
3. To propose actionable recommendations for curriculum reform, faculty development, and digital inclusion tailored to under-resourced TVET colleges.

1.3. Contextualising the research: Nkangala TVET College

Nkangala TVET College in Mpumalanga serves as a vital educational hub, particularly in rural contexts where access to higher learning is limited. Despite this role, the college struggles to keep pace with the demands of 4IR (table 1). Infrastructure is uneven: some campuses have computer labs and digital literacy programs, while others face unstable electricity and unreliable internet. The advanced integration of AI, VR, and learning management systems remains minimal. Government initiatives such

as the National Student Financial Aid Scheme (NSFAS) laptop rollouts offer support but remain hindered by logistical barriers. Many students arrive with little digital exposure, while educators lack confidence in 4IR pedagogy. Sustainable transformation requires institutional readiness, community engagement, and locally responsive strategies that address the needs of diverse communities.

Table 1

A SWOT analysis illustrating Nkangala’s strategic positioning.

Strengths	Weaknesses
Alignment with DHET reforms	Uneven infrastructure; limited 4IR tech
Commitment to inclusivity and entrepreneurship	Low staff readiness; student digital illiteracy
Strong community engagement	Limited AI/VR integration
Opportunities	Threats
Government digital device support	Deepening digital divide

2. Theoretical framework

This study employs the TAM to examine 4IR technology adoption in Nkangala TVET College. TAM explains adoption through perceived usefulness (PU), which is the belief that technology enhances task performance, and perceived ease of use (PEOU), which is the belief that technology use is effort-free. These constructs shape attitudes, behavioural intentions, and actual technology use, providing a structured lens to analyse stakeholder engagement with digital tools [11].

Figure 1 illustrates the core constructs of TAM, and table 2 contextualises them for Nkangala stakeholders, linking PU and PEOU to digital tools, infrastructure, and pedagogy. Limitations include its focus on individual cognition, which overlooks structural, institutional [1], and cultural factors such as infrastructure gaps, leadership support, and policy constraints [9].

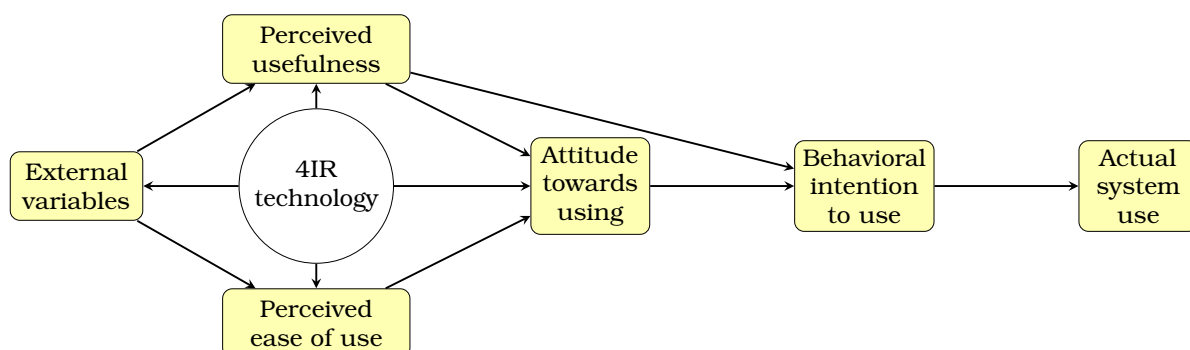


Figure 1: Technology acceptance model with 4IR technology.

UTAUT extends TAM by retaining PU and PEOU (renamed as performance expectancy and effort expectancy), while adding social influence and facilitating conditions, thereby capturing institutional and peer effects [5, 13]. Table 3 aligns TAM

Table 2

Contextualising TAM constructs for stakeholders’ technology adoption.

TAM construct	Contextual application
Perceived usefulness	Belief that 4IR technologies (LMS, simulations) improve teaching, engagement, and employability
Perceived ease of use	Confidence in using technologies despite limited infrastructure, connectivity, and digital skills
Attitude toward using	Overall disposition toward digital adoption shaped by experience, training, and institutional culture
Behavioural intention to use	Likelihood of continued technology use if sufficient support, training, and infrastructure exist

and UTAUT constructs. Applying UTAUT enables the study to account for multidimensional adoption factors, including peer pressure, managerial support, and infrastructure, providing a robust framework for interpreting stakeholder engagement with 4IR technologies in resource-constrained TVET contexts [17, 19].

Table 3

Aligning TAM and UTAUT constructs.

TAM construct	UTAUT construct
Perceived usefulness	Performance expectancy
Perceived ease of use	Effort expectancy
Behavioral intention	Behavioral intention
–	Social influence
–	Facilitating conditions

UTAUT was applied to assess how stakeholders at Nkangala TVET College experience the adoption of 4IR technology. Four core constructs guided the analysis:

1. *Performance expectancy* – the degree to which simulation tools, LMS, and other digital technologies are perceived to enhance learning outcomes [17].
2. *Effort expectancy* – stakeholders’ perceptions of technology ease of use given existing infrastructure and digital skills [9].
3. *Social influence* – the impact of peers, educators, and institutional norms on adoption behaviours.
4. *Facilitating conditions* – availability of training, IT support, and infrastructure to support technology use [2].

These variables were coded thematically using NVivo 12, enabling the identification of adoption patterns and barriers. UTAUT was selected over the theory of planned behaviour and diffusion of innovations due to its broader explanatory scope in contexts where institutional and social factors are pivotal.

UTAUT offers several advantages for this research context. First, it provides contextual breadth by capturing institutional, policy, and peer influences that are critical in under-resourced TVET settings [7]. Second, the framework demonstrates organisational relevance by accounting for managerial support and policy constraints that shape technology adoption decisions. Third, UTAUT exhibits stronger predictive validity, explaining behavioural intentions and adoption outcomes more effectively than TAM alone [10].

Despite its advantages, UTAUT introduces analytical complexity in qualitative research due to the multiple constructs that require nuanced interpretation [11]. Its generalised predictors may underrepresent cultural, historical, and socio-political realities in post-apartheid South African TVETs [16]. Facilitating conditions, often framed as external, can obscure individual agency, potentially minimising perceived autonomy in resource-constrained environments. Careful adaptation is therefore necessary to avoid oversimplifying the dynamics of adoption.

Literature highlights performance expectancy as a major facilitator, as digital tools such as virtual simulations and e-learning platforms have been shown to improve engagement and learning outcomes. Effort expectancy is similarly critical, with structured training and technical support shown to increase educator confidence [5]. Peer and managerial encouragement further drive innovation, aligning with the social influence construct of UTAUT.

At the same time, facilitating conditions remain uneven, particularly with respect to infrastructure, reliable internet, and device access, which hinder widespread integration. Barriers documented in recent studies include poor institutional support, inconsistent leadership commitment, and limited perceived behavioural control [18]. Subjective norms vary across departments, diluting momentum for collective digital transformation. In addition, some educators have expressed concerns about job displacement and the erosion of traditional pedagogy, highlighting emotional and historical factors not adequately explained by TAM or UTAUT [2].

3. Methodology

3.1. Study design and approach

The focus of this study was to examine lived experiences and institutional responses to digital transformation, which are best explored through qualitative inquiry [15]. To this end, the study employed a qualitative research design within an interpretivist paradigm, which is suitable for investigating stakeholders' perceptions and experiences of 4IR adoption in South African TVET colleges [20]. The interpretivist stance foregrounds participants' situated meanings and institutional practices, which are not readily captured through quantitative methods.

A multi-site case study was conducted across five Nkangala TVET College campuses, enabling cross-contextual comparisons while preserving the depth of inquiry [9]. This approach provided nuanced insights into the heterogeneity of experiences and practices across different institutional contexts while remaining grounded in the lived realities of participants.

3.2. Participants demographics and sampling

Participants were purposively selected for their direct involvement in 4IR-related teaching, learning, or institutional management within Nkangala TVET College, ensuring information-rich insights. Eligibility criteria included active engagement in institutional practice, exposure to at least one 4IR-aligned technology (e.g., LMS, simulation tools), and willingness to reflect on experiences critically. Recruitment used institutional gatekeepers and professional networks to achieve balanced representation across educators, students, and campus managers [5].

The final sample comprised 50 participants across five campuses: 5 campus managers, 25 educators from key academic departments (Engineering, ICT, and Business), and 20 students from NCV and NATED/Report 191 programs (table 4). Selection ensured participants could provide detailed, context-specific perspectives on digital transformation initiatives.

Table 4

Demographic profile of study participants.

Group	Number	Gender distribution	Experience / level
Campus managers	5	3 Male, 2 Female	5–15+ years in leadership roles
Educators	25	12 Male, 13 Female	2–20 years of teaching experience
Students	20	10 Male, 10 Female	NCV Level 4, N6, Report 191 programs

3.3. Sampling strategy

Purposive sampling targeted participants with first-hand experience in 4IR-related teaching, learning, or institutional policy. Recruitment across the five campuses ensured representation from all stakeholder groups, including educators, managers, and students, using institutional networks and gatekeeper referrals [5].

The study reached thematic saturation, confirmed during both data collection and preliminary analysis, as additional data no longer yielded new themes [12]. The participant distribution, comprising five campus managers, 25 educators, and 20 students, enabled triangulation across roles while maintaining diversity in terms of gender, experience, and academic field [19]. This approach ensured robust, context-specific insights into the adoption of 4IR in TVET colleges.

3.4. Data collection methods

Data were collected over six weeks using semi-structured in-depth interviews (IDIs) with managers and focus group discussions (FGDs) with educators and students, enabling capture of both individual and collective perspectives [20]. Interview guides were developed based on the TAM and UTAUT constructs and piloted to refine question phrasing and ensure contextual relevance. Sessions lasted 45–90 minutes, were audio-recorded, transcribed verbatim, and supplemented with field notes capturing nonverbal and contextual cues [4].

A single trained researcher conducted most sessions, following standardised protocols [23]. Neutral spaces minimised power imbalances, while pseudonyms (MAN1–MAN5 for managers, EDU1–EDU25 for educators, and STD1–STD20 for students) preserved anonymity. Ethical approval was granted by the university ethics committee (ethics approval number 2021/05/12/57643482/19/am), with participants informed of consent, voluntary participation, and withdrawal rights [20].

3.5. Data analysis

Braun and Clarke’s six-phase thematic analysis was applied, integrating inductive and deductive coding aligned with TAM/UTAUT constructs [21]. Transcripts were imported into NVivo 12 to enhance systematic coding, query generation, and visualisation: the steps included familiarisation, coding, candidate theme identification, theme refinement, naming, and mapping to research questions [12].

Analytical rigour was strengthened through independent double coding, peer debriefing with two qualitative experts, and NVivo-assisted cross-group comparisons. An audit trail of coding decisions and memos ensured transparency and traceability [13].

3.6. Ensuring reliability and rigour

Trustworthiness was operationalised through credibility, dependability, confirmability, and transferability. Credibility was reinforced via member checking and triangulation across IDIs, FGDs, and field notes. Dependability relied on audit trails, NVivo logs, and inter-coder checks. Confirmability was supported through reflexive journaling, which documented the researcher’s interpretations [23]. Transferability was enhanced through thick descriptions of campuses, participant roles, and programs [10, 16].

3.7. Challenges and limitations

Challenges included logistical coordination across five campuses, smaller FGDs among managers, and potential power hierarchies limiting open dialogue. Mitigations included neutral facilitation and separate FGDs by role [20]. Early NVivo technical issues were resolved via targeted training. While thematic saturation was reached, the breadth of the data constrained deeper probes into topics like job displacement; triangulation with literature enriched interpretation [4, 14]. Methodological integrity was maintained through member checking, peer debriefing, and participant diversity [13].

4. Discussion of findings

This study examined the integration of 4IR technologies in South African TVET colleges, capturing the perspectives of managers, educators, and students through semi-structured interviews and focus group discussions. Five key themes emerged: (1) persistent skills gaps impacting institutional readiness; (2) the potential of 4IR technologies to enhance graduate employability; (3) the importance of industry collaboration for innovation and entrepreneurship; (4) the tension between traditional skills and digital transformation; and (5) the need for context-sensitive, actionable policy frameworks. Findings are interpreted through the TAM and the UTAUT, which highlight the roles of perceived usefulness, effort expectancy, social influence, and facilitating conditions in shaping technology adoption [22].

4.1. Theme 1: Skills gaps and mismatches pose challenges in college preparedness

A recurring concern raised by participants was the misalignment between current curricula and the evolving demands of the digital economy. MAN3 stressed, “The skills gap created by the 4IR urgently needs attention, and it’s crucial that we realign our curricula to enhance graduates’ employability”, underscoring the urgency for systemic reform. EDU09 echoed this sentiment, lamenting, “We are still teaching from manuals written five or ten years ago. Industry has moved on, but we’re stuck”. Such outdated materials directly undermine pedagogical relevance.

Infrastructure and human resource constraints compound the problem. EDU6 explained, “We have the technology, but without the right infrastructure or training, it becomes difficult for us to implement it effectively”. Students, too, experience these gaps: STD11 admitted, “In class, we use paper. But companies ask if we know how to use software or digital tools. Sometimes we just say yes and hope to learn on the job”.

These challenges align with broader findings that vocational education often lags behind labour market requirements, leaving graduates underprepared for emerging roles [18]. The TAM highlights that uptake is shaped by perceived usefulness and ease of use. As MAN5 observed, “Some educators’ under-qualification in 4IR technologies is a significant hurdle to its adoption”.

Beyond technology, respondents stressed pedagogy. EDU11 argued, “We must rethink the way we teach if we are to successfully equip students for the digital age”, aligning with calls for innovation in teaching practices [1]. EDU16 similarly noted the importance of alignment with workplace skills, reflecting the UTAUT framework’s emphasis on facilitating conditions.

Bridging skills gaps, therefore, requires integrated curriculum reform, sustained professional development, and infrastructure investment [16].

4.2. Theme 2: The adoption of 4IR technologies enhances employability

Participants consistently emphasised that integrating 4IR technologies strengthens graduate employability. EDU10 stated, “Our curricula must evolve to prepare students

for a world where digital competencies are essential”, while EDU21 added, “The effective integration of technology into education requires a fundamental transformation of the teaching process, not just the addition of new tools”. These perspectives highlight that technology adoption is insufficient on its own; pedagogical innovation is equally critical [14].

Students affirmed the benefits of technology-enhanced learning. STD06 remarked, “Once we got used to online platforms and simulations, it felt like we were learning skills that apply to real jobs”, illustrating the direct link between digital exposure and workplace readiness. Nonetheless, barriers such as limited infrastructure, inadequate training, and reluctance among educators were frequently cited. MAN5 observed, “The biggest barrier to technology adoption is not the technology itself, but the willingness of educators to change their practices”, highlighting TAM’s perceived ease of use as a constraint.

UTAUT constructs reinforce the role of facilitating conditions, including access to hardware, IT support, and structured training. Industry partnerships emerged as significant enablers. EDU16 reflected, “The future of education is not about technology, but about how technology can enhance the human experience of learning”, underscoring that meaningful adoption extends beyond tool usage to improve pedagogical practices. Literature confirms that integrated technological and instructional strategies maximise employability, with infrastructure, educator training, and curriculum alignment serving as critical levers [11].

4.3. Theme 3: Industry collaboration enhances entrepreneurship and innovation focus

Participants consistently emphasised the importance of industry partnerships in promoting innovation, entrepreneurship, and employability. MAN2 observed, “TVET colleges have the potential to support small business start-ups, contributing to economic growth and fostering adaptability in the digital era”, reflecting TAM’s principle that perceived usefulness is enhanced when learners see tangible real-world outcomes. EDU4 noted, “Collaboration with industry partners is crucial in ensuring that our students are equipped with the skills and knowledge necessary to succeed in the digital economy”, corroborating the literature on the role of structured engagement in building innovation capacity.

Students emphasised the value of entrepreneurial skill development. STD12 remarked, “We need to go beyond just acquiring technical skills and focus on developing our entrepreneurial mindset and creative problem-solving abilities”, highlighting the UTAUT constructs of performance expectancy and social influence, where industry validation motivates engagement. However, inconsistent implementation was noted, with EDU9 cautioning that industry collaboration often falls short because there is no clear framework for how it should work, signalling the need for policy-guided, coordinated approaches. Sustained, structured partnerships enhance curriculum relevance, support pedagogical transformation, and enable students to develop entrepreneurial capacities, linking 4IR technology to practical, economically relevant applications.

4.4. Theme 4: The future of traditional skills in the 4IR

Participants highlighted that traditional vocational skills remain indispensable even amid 4IR-driven transformation. MAN2 asserted, “To navigate the 4IR landscape, TVET colleges must embrace the integration of traditional skills with emerging technologies, cultivating a new generation of innovators who seamlessly combine the strengths of both”. This perspective aligns with Ajigini and Chinamasa [3], emphasising the ongoing value of creativity, critical thinking, and problem-solving in automated environments. EDU15 added, “The future of education lies in the fusion of technical

expertise and human-centric abilities, empowering graduates to thrive in an era where traditional skills and innovation converge”, reflecting TAM’s assertion that adoption is strengthened when innovations complement, rather than replace, existing practices [10].

Students supported this hybrid approach. STD17 noted, “I think it’s really important to keep traditional skills alive. . . . At the same time, we need to learn modern skills to stay relevant in the job market”, highlighting the dual importance of cultural identity and professional adaptability. UTAUT emphasises that successful integration requires institutional support, adaptable curricula, and clear policy guidance. MAN3 cautioned that, “vocational training may be undervalued in favour of trend-driven skills”, signalling the risk of over-prioritising novelty at the expense of foundational competencies. Collectively, these insights suggest that a hybrid skills model enhances employability while preserving the pedagogical and cultural legacy of TVET education.

4.5. Theme 5: Associated policy recommendations

Policy development emerged as a central determinant of effective 4IR adoption. EDU12 emphasised, “We need policies that go beyond mere recommendations and provide concrete guidelines for implementation”, pointing to the importance of operational clarity. Similarly, EDU9 noted that “industry collaboration often falls short because there is no clear framework for how it should work”, illustrating the consequences of vague directives. Research aligns with these concerns, cautioning that policy rhetoric without operational mechanisms undermines institutional responsiveness [1].

From a theoretical perspective, TAM emphasises that effective policy enhances perceived usefulness, while UTAUT highlights the role of facilitating conditions, such as infrastructure and professional development. Participants repeatedly highlighted how policy gaps hinder capacity. MAN4 explained, “We are trying to innovate, but without policy support or consistent funding, it’s like building a house on sand”.

The issue of adaptability also surfaced strongly. STD13 remarked, “What works in urban colleges won’t always work in rural ones”, emphasising the need for context-sensitive frameworks. Such flexibility ensures that rural and under-resourced institutions are not left behind [7].

Participants called for multi-tiered policies that connect national strategy with local implementation, embedding curriculum reform, educator training, infrastructure development, and structured industry collaboration. Without such measures, 4IR adoption risks remaining superficial, limiting its potential to improve educational outcomes, workforce readiness, and broader socio-economic transformation.

5. Conclusion

5.1. Summary of findings

The integration of Fourth Industrial Revolution technologies in South African TVET colleges presents both significant challenges and transformative opportunities. Drawing on the TAM and the UTAUT, the findings show that successful adoption depends not only on perceived usefulness and ease of use but also on institutional support, adequate infrastructure, and coherent policy frameworks.

Empirical evidence highlights outdated curricula, insufficient educator training, and inadequate infrastructure as major barriers that undermine confidence and institutional momentum [17]. Stakeholders emphasised that digital integration, when supported by professional development, infrastructure investment, and alignment with industry demands, can strengthen graduate employability and workplace readiness. Industry partnerships emerged as key enablers, yet inconsistent implementation and fragmented policies limit their effectiveness [6]. Participants also called for a hybrid skills model that combines vocational competencies with digital literacy,

ensuring graduates remain competitive in a human-centred yet technologically evolving economy.

Globally, South Africa's challenges mirror those in Sub-Saharan Africa and South Asia, where infrastructure deficits and policy fragmentation slow 4IR adoption [2]. By contrast, advanced systems, such as those in Germany and Singapore, illustrate how sustained investment, industry engagement, and integrated policies can align vocational education with future labour needs [1]. South Africa stands at a critical juncture: digital transformation must bridge, rather than widen, socio-economic divides [22]. Key priorities include curriculum reform, scaled infrastructure, systemic faculty development, and formalised industry collaboration.

5.2. Implications and recommendations

The integration of 4IR technologies in South African TVET colleges requires a strategic and inclusive approach. First, curriculum reform must align industry-oriented digital competencies with traditional vocational skills, ensuring graduates remain employable in rapidly evolving markets. Equally important is sustained educator development to strengthen both technological expertise and innovative pedagogy. Persistent digital exclusion, particularly on rural and under-resourced campuses, also necessitates systemic interventions that promote access and equity.

Human-centric attributes, adaptability, problem-solving, and critical thinking, remain indispensable. When coupled with entrepreneurial mindsets fostered through interdisciplinary and industry-linked projects, these skills prepare learners to participate actively in the 4IR economy.

From these insights, five recommendations follow:

1. *Curriculum reform* involves periodic review via advisory councils that integrate digital and vocational skills.
2. *Educator development* requires nationally standardised, incentivised programs with continuous monitoring.
3. *Hybrid and inclusive learning* utilizes expanded blended models with investment in devices and connectivity [14].
4. *Innovation and entrepreneurship* are fostered by embedding hubs, interdisciplinary projects, and industry partnerships [7].
5. *Formalised industry collaboration* establishes structured partnerships, co-designed modules, and internships to strengthen the education and employment pipeline [9].

5.3. Future studies

Future studies should focus on the long-term employability and career outcomes of TVET graduates exposed to 4IR-integrated education, assessing whether digital literacy, problem-solving skills, and adaptability translate into sustained labour market success [16]. Comparative research across urban and rural colleges is also needed to examine disparities in infrastructure, educator readiness, and student engagement, supporting context-sensitive strategies for equitable implementation [5]. Additionally, engaging employers to evaluate graduate preparedness can inform curriculum design and strengthen industry-college partnerships [6].

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References

- [1] Abrahams, L. and Burke, M., 2022. *Report on the South African Experience in Open Digital Governance*. Johannesburg: LINK Centre, University of the Witwatersrand. Available from: <https://www.wits.ac.za/media/wits-university/research/tayarisha/documents/SA-EU-Dialogue-ODG-SA-experience.pdf>.
- [2] Ajigini, O.A., 2023. Adoption of Internet of Things in the Higher Educational Institutions: Perspectives from South Africa. *International Journal of Emerging Technologies in Learning (iJET)*, 18(16), p.165–181. Available from: <https://doi.org/10.3991/ijet.v18i16.42317>.
- [3] Ajigini, O.A. and Chinamasa, T.J.W., 2023. Modelling Digital Transformation Within the Financial Sector: A South African Perspective. *Information Resources Management Journal*, 36(1), p.1–20. Available from: <https://doi.org/10.4018/irmj.320642>.
- [4] Braun, V. and Clarke, V., 2022. *Thematic Analysis: A Practical Guide*. London: SAGE Publications Ltd.
- [5] Chanda, K.Z., 2023. *The role of artificial intelligence in fostering workplace integrated learning at a South African TVET College during COVID-19*. Master's thesis. University of Johannesburg. Available from: <https://ujcontent.uj.ac.za/esploro/outputs/graduate/The-role-of-artificial-intelligence-in/9932110007691>.
- [6] Department of Higher Education and Training, 2024. *Annual Performance Plan 2024/25*. Pretoria. Available from: <https://www.dhet.gov.za/Strategic%20Plans/Annual%20Performance%20Plans/DEPARTMENT%20OF%20HIGHER%20EDUCATION%20AND%20TRAINING%20ANNUAL%20PERFORMANCE%20PLAN%20FOR%202024-25%20FINANCIAL%20YEAR.pdf>.
- [7] Geriş, A. and Kulaksız, T., 2025. Predicting teachers' intentions to use virtual reality in education: a study based on the UTAUT-2 framework. *Research in Learning Technology*, 33, p.3429. Available from: <https://doi.org/10.25304/rlt.v33.3429>.
- [8] Government of South Africa, 2006. Continuing Education and Training Act (previously known as Further Education and Training Colleges Act) 16 of 2006. Available from: <https://www.gov.za/documents/further-education-and-training-colleges-act>.
- [9] Hashem, R., Ali, N., El Zein, F., Fidalgo, P. and Abu Khurma, O., 2024. AI to the rescue: Exploring the potential of ChatGPT as a teacher ally for workload relief and burnout prevention. *Research and Practice in Technology Enhanced Learning*, 19, p.023. Available from: <https://doi.org/10.58459/rptel.2024.19023>.
- [10] Kgosi, M., Makgato, M. and Skosana, N., 2023. Teachers' Views on the Application of Educational Technologies in the Classroom: A Case of Selected Tshwane West Secondary Schools in Gauteng. *Journal of Curriculum Studies Research*, 5(2), pp.151–166. Available from: <https://doi.org/10.46303/jcsr.2023.23>.
- [11] Khoza, S.B., 2023. Can Teachers' Identities Come to the Rescue in the Fourth Industrial Revolution? *Technology, Knowledge and Learning*, 28(2), pp.843–864. Available from: <https://doi.org/10.1007/s10758-021-09560-z>.
- [12] Korstjens, I. and Moser, A., 2018. Series: Practical guidance to qualitative research. Part 4: Trustworthiness and publishing. *European Journal of General Practice*, 24(1), pp.120–124. Available from: <https://doi.org/10.1080/13814788.2017.1375092>.
- [13] Maher, C. and Bedwei-Majdou, C., 2024. Semi-structured Qualitative Interview Guide: Process and Considerations for Doctoral Students. In: R. Throne, ed. *Qualitative Research Methods for Dissertation Research*. Hershey, PA: IGI Global Scientific Publishing, p.195–220. Available from: <https://doi.org/10.4018/>

979-8-3693-3069-2.ch007.

- [14] McLaren, B.M. and Nguyen, H.A., 2023. Digital Learning Games in Artificial Intelligence in Education (AIED): A Review. In: B. du Boulay, A. Mitrovic and K. Yacef, eds. *Handbook of Artificial Intelligence in Education*. Edward Elgar Publishing, chap. 20, pp.440–484. Available from: <https://doi.org/10.4337/9781800375413.00032>.
- [15] Mertens, D.M., 2023. *Research and Evaluation in Education and Psychology: Integrating Diversity with Quantitative, Qualitative, and Mixed Methods*. 6th ed. SAGE Publications, Inc.
- [16] Mhlanga, D. and Moloi, T., 2020. COVID-19 and the Digital Transformation of Education: What Are We Learning on 4IR in South Africa? *Education Sciences*, 10(7), p.180. Available from: <https://doi.org/10.3390/educsci10070180>.
- [17] Mhlongo, K.M., Khoza, S.D. and Skosana, N.M., 2023. The Significance of Hand Tool Skills in the Fourth Industrial Revolution: A Focus on the Construction Concept. *Jurnal Penelitian dan Pengkajian Ilmu Pendidikan: e-Saintika*, 7(1), p.1–17. Available from: <https://doi.org/10.36312/esaintika.v7i1.1026>.
- [18] Nayyar, G., Pleninger, R., Vorisek, D. and Yu, S., 2024. *Digitalization and Inclusive Growth: A Review of the Evidence*. (Policy Research Working Paper, 10941). World Bank. Available from: <https://openknowledge.worldbank.org/server/api/core/bitstreams/811165b6-3c51-4acb-8e09-9f5aa6364106/content>.
- [19] Razalli, A.R., Idris, N., Jamil, M.R.M., Ismail, R., Janudin, S.E. and Azmi, S.H., 2025. A Quantitative Study on Graduate Employability: Insights from Sultan Idris Education University, Malaysia. *International Journal of Research and Innovation in Social Science*, VIII(XII), p.2127–2142. Available from: <https://doi.org/10.47772/ijriss.2024.8120179>.
- [20] Roller, M.R. and Lavrakas, P.J., 2015. *Applied Qualitative Research Design: A Total Quality Framework Approach*. New York: Guilford Press.
- [21] Wang, S., Wang, H., Jiang, Y., Li, P. and Yang, W., 2023. Understanding students' participation of intelligent teaching: an empirical study considering artificial intelligence usefulness, interactive reward, satisfaction, university support and enjoyment. *Interactive Learning Environments*, 31(9), pp.5633–5649. Available from: <https://doi.org/10.1080/10494820.2021.2012813>.
- [22] Yang, X. and Wu, W., 2024. Advancing digital transformation in TVET through international cooperation: Approaches by the UNESCO Chair on Digitalization in TVET. *Vocation, Technology & Education*, 1(2). Available from: <https://doi.org/10.54844/vte.2024.0585>.
- [23] Younas, A., Fàbregues, S., Munce, S. and Creswell, J.W., 2025. Framework for types of metainferences in mixed methods research. *BMC Medical Research Methodology*, 25(1), p.18. Available from: <https://doi.org/10.1186/s12874-025-02475-8>.

A. Data collection instruments

A.1. Campus manager interview guide: 4IR in South African TVET colleges

Date of interview: _____

Place of interview: _____

Thank you for participating in this interview. We are interested in your views on how Fourth Industrial Revolution (4IR) technologies are being integrated within South African TVET Colleges. The goal is to understand your experiences, challenges, and strategic role in advancing digital transformation at your institution.

Please do not provide your name; your identity will remain anonymous, and your confidentiality is fully protected. No comments will be linked back to you personally.

Interview questions for campus managers:

1. Please tell us a little about yourself, including your study focus, academic qualifications, and management experience.
2. How would you describe your college's current state of readiness for 4IR integration?
3. What 4IR technologies have been introduced on your campus? How were these received by staff and students?
4. In your opinion, how useful are these technologies for improving teaching, learning, and graduate outcomes?
5. What challenges does your campus face in adopting or scaling 4IR technologies (e.g., infrastructure, training)?
6. What role does national or provincial policy play in supporting your campus's digital transformation?
7. How would you evaluate the digital literacy and adaptability of your staff and students?
8. Are there structured collaborations with industry? If so, how do they shape 4IR readiness?
9. How does the institution support professional development for educators in using digital tools?
10. What impact do you foresee 4IR having on traditional vocational skills and job roles?
11. What strategic steps has your campus taken to align with 4IR-related policy and curriculum reforms?
12. What recommendations would you make for strengthening 4IR integration at your institution or nationally?

Thank you for your time and participation in this discussion.

A.2. Educator focus group discussion schedule: 4IR in South African TVET colleges

Date of focus group discussion: _____

Place of focus group discussion: _____

Greetings and welcome! This focus group aims to explore your perceptions and experiences as educators regarding the adoption of Fourth Industrial Revolution (4IR) technologies in South African TVET Colleges. The discussion is guided by the technology acceptance model (TAM) and the unified theory of acceptance and use of technology (UTAUT).

You were invited because, as a TVET educator, you are assumed to have valuable insights into the sector's role in national development and addressing youth unemployment. Please do not share your name; your responses will remain anonymous, and your confidentiality is fully assured.

Discussion prompts for educators:

1. Please tell us a little about yourself, including your study focus, academic qualifications, and teaching experience.
2. What technologies (e.g., LMS, simulations, online platforms) are currently used in your teaching practices?

3. How have these technologies influenced student engagement, learning outcomes, and employability?
4. What are the main challenges you face when using 4IR tools (e.g., training, infrastructure, time)?
5. How confident do you feel in using these tools? What support or training have you received?
6. How do students respond to the use of 4IR technologies in class?
7. How do peer support and institutional culture affect your use of technology?
8. What are your thoughts on the relevance of your current curriculum to the 4IR skills agenda?
9. Have you participated in any innovation, entrepreneurship, or industry-linked initiatives related to 4IR?
10. What changes would you like to see in institutional policy or support to better integrate 4IR tools?
11. How can the integration of traditional and digital skills be balanced in vocational education?

Thank you for your time and participation in this discussion.

A.3. Student focus group discussion schedule: 4IR in South African TVET colleges

Date of focus group discussion: _____

Place of focus group discussion: _____

Welcome, and thank you for participating! This focus group discussion aims to explore your views on the use of Fourth Industrial Revolution (4IR) technologies in South African TVET colleges. We're interested in your experiences with digital tools, the challenges you face, and how these technologies impact your learning and career prospects.

You were invited because your insights are valuable. As a student, you can best describe how technology is used at your college, what works well, and what could be improved. You do not need to share your name; your responses will remain anonymous and confidential.

Discussion prompts for students:

1. Could you briefly introduce yourself (name optional), your course, and what motivated you to enroll in this course?
2. What types of technology have you used during your studies at the college?
3. How easy or difficult is it for you to use these technologies for learning?
4. Do you feel that the use of technology in your learning helps you prepare for your future job? Why or why not?
5. What challenges do you face when trying to access or use digital learning platforms or tools?
6. How do your lecturers incorporate technology into teaching, and how does it affect your learning experience?
7. Have you received any training or support to improve your digital skills?
8. What role does internet access, device availability, or electricity play in your ability to use 4IR technologies?
9. Are there any projects or activities at the college that involve new technology or digital skills?

10. Do you feel your curriculum reflects the skills you need for jobs in a digital economy?
11. What suggestions do you have for improving digital learning at your campus?

Thank you for your time and valuable contributions to this study.