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Challenges of Digitalisation in TVET: A Recent Comprehensive Structured Review

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Abstract. Technical and Vocational Education and Training (TVET) systems face both significant opportunities and complex challenges amid rapid global digital transformation. This systematic literature review (SLR) sought to identify and examine the key challenges associated with digitalisation of TVET. Central to the investigation was the persistent gap between the increasing demand for digital competencies and the capacity of TVET institutions to effectively adopt and implement digital tools and pedagogical practices. To address this issue, a search was conducted comprehensively across three academic databases, Scopus, Web of Sciences, and ERIC targeting peer-reviewed literature published from year 2022 to 2024. Searches employed combinations of keywords such as "TVET", "digitalisation", "vocational", "technical" and "skills". Inclusion criteria comprise English-language, peer-reviewed journal articles focusing on TVET and digitalisation, while non-articles and unrelated studies were excluded. From initial pool of 599 records, the final of 37 primary studies was selected for in-depth analysis. The findings were organised into three themes which were (1) digital transformation and curriculum development, (2) digital competence and skills development, and (3) digital inequality and inclusivity. The analysis revealed that while digital transformation offers substantial benefits, it also worsens existing inequalities and poses significant challenges in curriculum design and skill acquisition. Digital transformation in TVET offers substantial benefits such as flexible learning access and industry- relevant training, but also presents significant challenges in curriculum alignment, educator digital competence, and equitable resource distribution. These insights are crucial for policymakers, educators, and stakeholders aiming to optimise the digitalisation process within TVET systems.

Keywords: challenges; digitalisation; TVET; PRISMA; vocational education

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1. Introduction

TVET has been recognised as a crucial driver for economic growth and social development, particularly in emerging economies. The country's rapid industrialisation and the transition towards a knowledge-based economy have underscored the importance of equipping the workforce with relevant skills and competencies (Almatari et al., 2024). In this context, digitalisation presents both an unprecedented opportunity and a significant challenge for the TVET system. While digital technologies have the potential to enhance the deliver, accessibility, and relevance of TVET programs, they also introduce a range of complexities that need to be addressed to ensure the successful integration of these technologies into the educational framework.

The shift towards digitalisation in TVET is driven by several factors, including the increasing demand for digital skills in the job market, the need for more flexible and accessible learning models, and the government's push towards digital transformation under initiatives like the Fourth Industrial Revolution (IR 4.0) and the National Digital Economy Blueprint (M. Rokeman et al., 2024). These policies reflect commitment to develop a digitally competent workforce capable of thriving in an increasingly globalised and technologically advanced environment. However, the process of integrating digital tools and methodologies into TVET is filled with challenges that can impede its effectiveness and sustainability(Ismail et al., 2017).

A key challenge is the digital divide, especially in rural and disadvantaged areas (Arbine et al., 2024). Unequal access to digital infrastructure affects education quality and deepens socio-economic gaps. Limited digital literacy among educators and students also hinders effective digital TVET implementation. Many instructors lack training in using digital tools, affecting teaching quality (Ismail et al., 2017). Another issue is aligning digital TVET curricula with fast-evolving industry needs, requiring constant updates and collaboration between institutions, industry, and policymaker (Jamil et al., 2023) . Lastly, the high cost of digitalisation which involve technology, training, and content poses financial strain, especially without sufficient government support (Thomas et al., 2024).

While these challenges are well acknowledged, most existing studies examine them in isolation, focusing on specific issues such as skills, pedagogy or infrastructure. Few attempts have been made to synthesize the full range of challenges within a systematic and structured framework, particularly in the context of developing economies. This gap underscores the need for a comprehensive review that consolidates available evidence to provide clearer insights for policy and practice.

This study addresses the gap by conducting a SLR guided by PRISMA framework, drawing evidence from three major databases and categories into three thematic areas. This structured synthesis provides a holistic understanding that has not been comprehensively presented in earlier literature. As a conclusion, the main objective of this study is therefore to systematically review and synthesize recent literature on the challenges of

digitalization in TVET, with the aim of identifying key thematic areas and highlighting implications for policymakers, educators, and institutional leaders.

2. Literature Review

The digitalisation of TVET has become a focal point in education systems worldwide, particularly in the wake of the Fourth Industrial Revolution and the COVID-19 pandemic. Scholars have highlighted the multifaceted nature of this transformation, exploring both opportunities and challenges (Ismail et al., 2022).

A recurring theme is the need for digital competence among educators, particularly in using online platforms such as Google Classroom (Ferri et al., 2020). However, many educators face a steep learning curve due to insufficient training and lack of confidence in utilising these technologies effectively (Shamsudin et al., 2023). Similarly, while Nikonova et al. (2023) observe the potential of Artificial Intelligence (AI) tools to enhance pedagogy, they also caution that such innovations demand clearer frameworks to guide teachers in their use. This reflects a broader tension between the rapid development of digital tools and the slower pace of pedagogical adaptation.

Another critical theme concerns access to technology and the digital divide particularly in developing countries. Elrayah and Alshiha (2024) show that disparities in internet access, device availability, and technical infrastructure significantly hinder the effectiveness of digital TVET initiatives. These challenges are particularly pronounced in rural or underserved regions where reliable electricity or connectivity remain limited. This technological gap not only limits participation in online learning but also deepens existing educational inequalities.

Aina et al. (2022) observe that low levels of digital literacy reduce the benefits of technology-enhanced learning, while Kováčiková and Kic-Drgas (2023) report that pre-service teacher education in countries such as Slovakia and Poland often lacks systematic strategies for embedding digital competencies into pedagogical practice. Collectively, these finding suggest that bridging the digital divide requires more than infrastructure investment, demands continuous professional development, inclusive policy interventions and community-level digital empowerment.

Digitalisation is also transforming TVET curricula and learning outcomes. Increasingly, vocational training integrates digital literacy, sustainability, and transversal skills alongside technical expertise to align with the evolving needs of Industry 4.0 (Jewpanya et al., 2023). Pagkratis (2024) argues that future-ready TVET must go beyond technical proficiency to include competencies such as environmental awareness, collaboration, critical thinking, and adaptability skills vital for addressing the challenges of a green economy.

These emerging priorities reflect broader shifts in labour market expectations, where employers increasingly seek digitally fluent workers who are also capable of problem-solving and teamwork. Similarly, Dörpinghaus et al. (2024) highlight

the role of informatics education in fostering lifelong digital competencies, particularly through continuing vocational education and training (CVET), so workers remain adaptable in rapidly changing industries.

Another strand of literature explores how digital communication technologies are reshaping TVET governance and administration. Onajite et al. (2024) highlight that digital platforms enhance transparency, engagement, and interactivity in TVET training delivery, particularly within public sector setting where real-time feedback and data management are critical. In parallel, Hrechanyk et al. (2023) document the growing adoptation of hybrid and blended learning models across higher education which combine digital and face-to-face instruction. While these models were initially emergency responses during pandemic, they are increasingly seen as sustainable pedagogical approaches that can also be adapted to vocational training contexts.

The literature reveals that digitalisation in TVET is shaped by interrelated challenges of access, educator competence, curriculum transformation, and governance. Yet, most of the existing research treats these dimensions in isolation, providing fragmented insight rather than a consolidated overview. While higher education higher education has been the subject of several systematic reviews on digitalisation, such as holistic syntheses remain lacking in the context of TVET particularly in developing economies. This lack of integrative reviews limits policymakers' and challenges comprehensively. To address this gap, the present study undertakes a systematic literature review guided by the PRISMA framework, organising the evidence into three thematic areas.

3. Aims and Research Questions

In the context of a systematic literature review (SLR), formulating clear and focused research questions was a critical foundational step that guides the overall direction and scope of the study. Specifying research questions was not only essential at the planning stage but serves as the cornerstone of the entire SLR methodology (Kitchenham et al., 2007). To ensure clarity and structure in question development, this review employed the PICo framework an established tool for qualitative evidence synthesis.

The PICo model comprises three key components: Population (P), referring to the targeted group or participants of interest; Interest (I), denoting the phenomenon or issue being investigated; and Context (Co), which describes the setting or environment in which the study is situated (Kitchenham et al., 2004). This framework ensures that the questions are systematically formulated, comprehensive, and aligned with the review objectives. Guided by the PICo framework and the overarching aim of this review to explore the challenges of digitalisation in TVET education, three primary research questions have been developed based on the identified thematic areas:

1. How does digital transformation influence the development and implementation of curricula in TVET institutions in the post-pandemic era?
2. What are the key challenges in developing digital competences and skills among TVET students and educators within digital learning environments?

3. How does digital inequality impact inclusivity in TVET education systems across different socio-economic contexts?

These research questions served as the analytical lens through, which relevant literature was selected, examined, and interpreted. They were designed to provide a comprehensive understanding of the state of research, identify prevailing gaps, and offer insights for future advancements in TVET.

4. Methodology

This study adopted a systematic literature review (SLR) approach, guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. The PRISMA protocol ensures methodological transparency, comprehensiveness, and rigour by providing a structured process for identification, screening, eligibility assessment, and inclusion of relevant studies (Moher et al., 2009).

Three major databases Scopus, Web of Science, and ERIC, were selected for the search process because of their robust coverage of peer-reviewd academic literature. Scopus indexes multidisciplinary research, Web of Science provides extensive scholarly content and citation data, and ERIC specialises in educational studies. However, all databases have limitations, such as incomplete coverage or varying detail, which must be acknowledged (Harzing et al., 2016; Strayer, 2008).

There are four key phases: identification, screening, eligibility, and data abstraction involved in PRISMA framework. In the identification phase, a broad database search was conducted to collect potentially relevant studies. Screening followed, applying exclusion criteria to remove irrelevant records (Page et al., 2021). Eligibility involved detailed assessment against inclusion criteria. Finally, data abstraction systematically extracted and synthesised data from selected studies. This structured process ensured methodological integrity, improving the reliability and relevance of review outcomes for future research.

4.1 Search Strategy and Screening Process

In this study, the core procedures of the systematic review methodology were systematically applied to gather a comprehensive and relevant body of literature. The process began with the identification of key search terms, which was subsequently expanded through the examination of related terminology using dictionaries, thesauri, encyclopaedias, and insights from prior research.

Table 1: The search string

Databases	Search string
Scopus	TITLE-ABS-KEY (challenge* AND (digitalization OR digitalisation) AND ("TVET" OR vocational OR skills OR technical) AND education) AND (LIMIT-TO (SRCTYPE , "j")) AND (LIMIT-TO (SUBJAREA , "SOCI")) AND (LIMIT-TO (DOCTYPE , "ar")) AND (LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR , 2024)) AND (LIMIT-TO (LANGUAGE , "English")) **Date of Access: December 2024**
Eric	(challenge* AND (digitalisation OR digitalisation) AND ("TVET" OR vocational OR skills OR technical) AND education) **Date of Access: December 2024**
WOS	TS = (challenge* AND (digitalisation OR digitalisation) AND ("TVET" OR vocational OR skills OR technical) AND education) and 2022 or 2023 or 2024 (Publication Years) and Article (Document Types) and English (Languages) and Education Educational Research (Research Areas) and Education Educational Research (Research Areas) **Date of Access: December 2024**

All pertinent keywords were identified, and corresponding search strings were formulated for use in the ERIC, Web of Science (WOS), and Scopus databases (see Table 1). This initial stage of the systematic review yielded a total of 599 publications relevant to the study topic across the three databases, Scopus (n=508), WOS(n=72) and Eric (n=15).

During the screening stage, each study was reviewed to verify its alignment with the established research questions. This phase typically involved selecting studies that address the challenges of digitalisation in TVET, with duplicate papers being removed. Study selection followed the PRISMA 202 guidelines (Page et al., 2021) to ensure transparency and consistency. Inclusion criteria were peer-reviewed and scholarly works providing practical recommendations, published in English between 2022-2024 and directly relevant to digitalisation in TVET. Exclusion criteria included duplicates, non-English publications, unavailable full texts, and studies outside the review scopes. In total, 510 records were excluded, 89 retained for evaluation, and 4 later removed as duplicates (see Table 2).

Table 2: The selection criterion is searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2022 – 2024	< 2022
Literature type	Journal (Article)	Conference, Book, Review
Publication Stage	Final	In Press
Subject	Social science, Educational Research	Besides Social science, Educational Research

In the eligibility phase, a total of 85 articles underwent thorough assessment. Each article's title and main content were carefully examined to evaluate their consistency with the established inclusion criteria and the aims of the present study. Following this evaluation, 48 articles were excluded due to factors such as irrelevance to the research area, abstracts not aligning with the study's objectives,

or unavailability of the full text. Ultimately, 37 articles met the eligibility requirements and were included for further analysis.

4.2 Data Abstraction and Analysis

This study employed an integrative analysis approach as part of its evaluation strategy to explore and synthesise findings form diverse research designs.

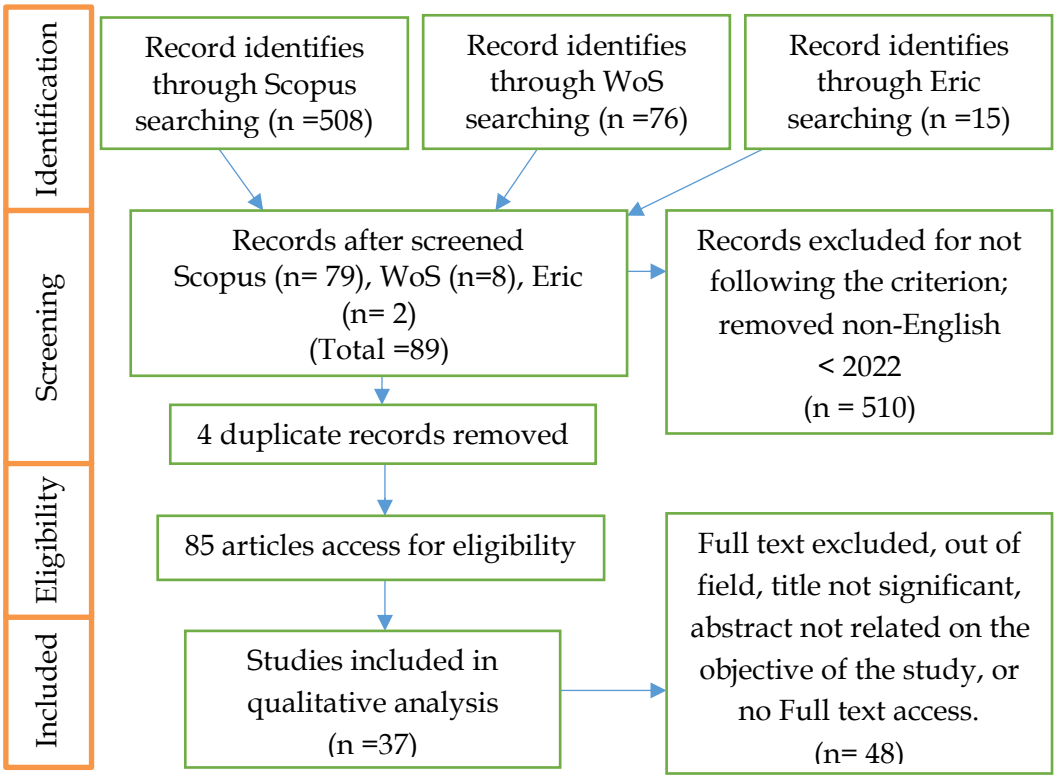

Figure 1: Flow diagram of the proposed searching study

This study aimed to identify key topics and subtopics. As illustrated in Figure 1, the authors conducted a detailed analysis of 37 selected publications to extract statements to the study's objectives. This was followed by a critical examination of existing literature. The methodologies and findings of these studies were thoroughly reviewed. Subsequently, the author collaborated with co-authors to inductively derive themes grounded in the contextual evidence. Finally, the identified themes were cross validated among the authors to ensure consistency. Any discrepancies in theme development were resolved through discussion and consensus.

4.3 Quality of Appraisal

Once the primary studies (PSs) were selected, it was necessary to assess their quality and perform a quantitative comparison (Kitchenham & Charters, 2007) . In this study, the quality assessment framework proposed by Abouzahra et al. (2020) was adopted, consisting of six quality assessment (QA) criteria applied to the systematic literature review (SLR) (see Table 3). Each criterion was evaluated using a standardised scoring procedure: a score of 1 was assigned if the criterion was fully met ("Yes"), 0.5 if it was partially met with minor deficiencies ("Partly"), and 0 if the criterion was not met ("No").

Table 3: Quality of Appraisal

Quality Assessment	Expert 1	Expert 2	Expert 3	Total Mark
"Is the purpose of the study clearly stated?"	Y	Y	Y	3
"Is the interest and the usefulness of the work clearly presented?"	Y	Y	Y	3
"Is the study methodology clearly established?"	Y	Y	Y	3
"Are the concepts of the approach clearly defined?"	Y	Y	Y	3
"Is the work compared and measured with other similar work?"	Y	Y	Y	3
"Are the limitations of work clearly mentioned?"	Y	Y	Y	3

Each expert conducted an independent evaluation of the studies based on the predefined criteria. The individual scores assigned by the three experts were then aggregated to produce a composite score for each study. To qualify for inclusion in the subsequent analysis, a study was required to achieve a cumulative score greater than 3.0. This scoring threshold was established to ensure that only studies meeting a minimum standard of quality were advanced for further consideration.

5. Result and Discussion

This section presents the findings of the systematic review and provides a critical discussion in relation to existing literature. Background of selected study:

No	Authors	Title	Year	Journal	Scopu	Wo S	Eric
1	Mielikäinen M.; Viippola E.(Mielikäinen & Viippola, 2023)	"ICT Engineering Students' Perceptions on Project-Based Online Learning in Community of Inquiry (CoI)"	2023	SAGE Open	/		
2	Shamsudin A.; Mamat S.N.; Pauzi N.F.M.; Karim M.S. (Shamsudin et al., 2023)	"Adapting to Changing Expectations: Accounting Students in the Digital Learning Environment"	2023	International Journal of Information and Education Technology	/		
3	Sinervo L.-M.; Kork A.-A.; Hasanen K. (Sinervo et al., 2023)	"Challenges in curriculum development process aimed at revising the capabilities of future public financial managers"	2023	Teaching Public Administrati on	/		
4	Taylor-Beswick A.M.L. (Taylor-Beswick, 2023)	"Digitalizing social work education: preparing students to engage with twenty-first century practice need"	2023	Social Work Education	/		

5	Klopov I.; Shapurov O.; Voronkova V.; Nikitenko V.; Oleksenko R.; Khavina I.; Chebakova Y. (Klopov et al., 2023)	"Digital Transformation of Education Based on Artificial Intelligence"	2023	TEM Journal	/		
6	Shestakova I.; Morgunov V. (Shestakova & Morgunov, 2023)	"Structuring the post-COVID-19 Process of Digital Transformation of Engineering Education in the Russian Federation"	2023	Education Sciences	/		
7	Pushkarna N.; Daly A.; Fan A. (Pushkarna et al., 2022)	"Teaching digital and global law for digital and global students: creating students as producers in a Hong Kong Internet Law class"	2022	Law Teacher	/		
8	Butcher L.; Ferguson G. (Butcher & Ferguson, 2023)	"Harnessing 'play' (beyond games) to enhance self-directed learning in VET"	2023	Journal of Vocational Education and Training	/		/
9	Strielkowski W.; Korneeva E.N.; Sherstobitova A.A.; Platitzyn A.Yu. (Strielkowski et al., 2022)	"Strategic University Management in the Context of Digitalization: The Experience of the World's Leading Universities"	2022	Integration of Education	/		
10	Bidzilya Y.M.; Rusynko-Bombyk L.M.; Solomin Y.O.; Hetsko H.I.; Barchan O.V. (Bidzilya et al., 2022)	"Implementation of the of Lifelong Learning Principles as a Background for Quality Specialized Education of Journalists"	2022	Journal of Curriculum and Teaching	/		
11	Colombari R.; Neirotti P. (Colombari & Neirotti, 2022)	"Closing the middle-skills gap widened by digitalization: how technical universities can contribute through Challenge-Based Learning"	2022	Studies in Higher Education	/		
12	Carlsson S.; Willermark S. (Carlsson & Willermark, 2023)	"Teaching Here and Now but for the Future: Vocational Teachers' Perspective on Teaching in Flux"	2023	Vocations and Learning	/		
13	Fjeldheim S.; Kleppe L.C.; Stang E.; Støren-Vaczy B. (Fjeldheim et al., 2024)	"Digital competence in social work education: readiness for practice"	2024	Social Work Education	/		

14	Dovleac L.; Chițu I.B.; Nichifor E.; Brătucu G. (Dovleac et al., 2023)	"Shaping the Inclusivity in the New Society by Enhancing the Digitainability of Sustainable Development Goals with Education"	2023	Sustainability (Switzerland)	/		
15	Zaimakis Y.; Kokkinou C. (Zaimakis & Kokkinou, 2023)	"Digital and Social Inequalities and the Post-Coronial University: A Greek Case"	2023	Urbanities	/		
16	Pramila-Savukoski S.; Kärnä R.; Kuivila H.-M.; Juntunen J.; Koskenranta M.; Oikarainen A.; Mikkonen K. (Pramila-Savukoski et al., 2023)	"The influence of digital learning on health sciences students' competence development– A qualitative study"	2023	Nurse Education Today	/		
17	Kalugina T.N.; Timchenko M.V. (Kalugina & Timchenko, 2023)	"Digitalization of Higher Education in 2021 – Challenges for University Students In Russia"	2023	Galactica Media: Journal of Media Studies	/		
18	Arfaoui F.; Kammoun I. (Arfaoui & Kammoun, 2023)	"Did accounting education remain resistant to digitalization during COVID-19? An exploratory study in the Tunisian context"	2023	Journal of Accounting Education	/		
19	Mamaeva E.A.; Markov R.V.; Shilova Z.V.; Zabelina S.B.(Mamaeva et al., 2023)	"Formation of critical thinking of future teachers while designing a quest as a collection of puzzles"	2023	Perspektivy Nauki i Obrazovania	/		
20	Zeverte-Rivza S.; Brence I.; Gudele I.; Rivza B.; Rivza P.(Zeverte-Rivza et al., 2024)	"Digitalization Risks in the Bioeconomy: An Enterprise-Level Perspective"	2024	Sustainability (Switzerland)	/		
21	Ibraimkulov A.; Khalikova K.; Yerimbetova A.; Gromaszek K. (Ibraimkulov et al., 2022)	"Enhancement of Digital Literacy of Students with Disabilities"	2022	European Journal of Contemporary Education	/		
22	Beerkens M. (Beerkens, 2022)	"An evolution of performance data in higher education governance: a path towards a 'big data' era?"	2022	Quality in Higher Education	/		

23	Kirchhoff S. (Kirchhoff, 2022)	"Journalism Education's Response to the Challenges of Digital Transformation: A Dispositive Analysis of Journalism Training and Education Programs"	2022	Journalism Studies	/		
24	Stare J.; Klun M.; Dečman M.(Stare et al., 2023)	"A Case Study on the Development of Digital Competences of Teachers at the University of Ljubljana"	2023	NISPAcee Journal of Public Administration and Policy	/		
25	Pina Stranger A.; Varas G.; Mobuchon G. (Pina Stranger et al., 2023)	"Managing Inter-University Digital Collaboration from a Bottom-Up Approach: Lessons from Organizational, Pedagogical, and Technological Dimensions"	2023	Sustainability (Switzerland)	/		
26	Thyssen C.; Huwer J.; Irion T.; Schaal S. (Thyssen et al., 2023)	"From TPACK to DPACK: The "Digitality-Related Pedagogical and Content Knowledge"-Model in STEM-Education"	2023	Education Sciences	/		
27	Hertling S.F.; Back D.A.; Eckhart N.; Kaiser M.; Graul I. (Hertling et al., 2022)	"How far has the digitization of medical teaching progressed in times of COVID-19? A multinational survey among medical students and lecturers in German-speaking central Europe"	2022	BMC Medical Education	/		
28	Yang C.; Kaiser F.; Tang H.; Chen P.; Diao J. (Yang et al., 2023)	"Sustaining the Quality Development of German Vocational Education and Training in the Age of Digitalization: Challenges and Strategies"	2023	Sustainability (Switzerland)	/		
29	Sá M.J.; Serpa S. (Sá & Serpa, 2022)	"Higher Education as a Promoter of Soft Skills in a Sustainable Society 5.0"	2022	Journal of Curriculum and Teaching	/		
30	Hrynevych L.; Linnik O.; Herczyński J. (Hrynevych et al., 2023)	"The new Ukrainian school reform: Achievements, developments and challenges"	2023	European Journal of Education	/	/	
31	Lucas M.; Vicente P.N. (Lucas & Vicente, 2023)	"A double-edged sword: Teachers' perceptions of the	2023	Education and	/		

		benefits and challenges of online teaching and learning in higher education"		Information Technologies			
32	Bax S.; Kroon S.; Spotti M. (Bax et al., 2024)	"Afterword L1 Education Between Von Humboldt And Chat GPT"	2024	L1 Educational Studies in Language and Literature	/		
33	Mariella Yuliana C.A.; Gisella Socorro F.M.; Aurelio R.P.; Sara Edith C.O. (Mariella Yuliana C.A. et al., 2022)	"Gamification in the reading comprehension of students in times of pandemic in Peru"	2022	Revista de Ciencias Sociales	/		
34	Sukumaran S.; Abdullah N.; Thiagarajah S.; Shahid N.S.M.; Yi H. (Sukumaran et al., 2023)	"Sound E-Learning of STEM in Malaysian Higher Education Institutions"	2023	Educational Administration: Theory and Practice	/		
35	Peters A.; Thon A. (Peters & Thon, 2024)	"Digital Transformation in University Landscape Architecture Education: Integrating Future Skills in Implementation Planning"	2024	Journal of Digital Landscape Architecture	/		
36	Kuntadi I.; Ana; Rohendi D.; Suryadi D.; Halim F.A.; Sari A.R.; Muktiarni; Dwiyanti V. (Kuntadi et al., 2022)	"Towards Digital TVET: A Comparative Study on Students' Readiness in The Industry Digital Demands in Indonesia and Malaysia"	2022	Journal of Technical Education and Training	/		
37	Schumacher K.; Duch F.; Sielaff L. (Schumacher et al., 2022)	"Creating an Online Social Learning Platform: A Model Approach for Open Development, Open Access and Open Education"	2022	Education Sciences	/		

The final themes were refined to ensure internal consistency and conceptual coherence. The thematic analysis underwent expert validation by a panel of three specialists, two with expertise in TVET education and one specialising in digitalisation within the TVET context to assess the relevance and validity of the identified issues. This expert review phase was instrumental in establishing domain validity by evaluating the clarity, significance, and appropriateness of each sub-theme. To address any discrepancies that emerged during theme development, the authors engaged in collaborative discussions until consensus was reached. Revisions and adjustments were subsequently made based on expert feedback and align with the study's objectives.

5.1 Theme 1: Digital Transformation and Curriculum Development

The theme of "Digital Transformation and Curriculum Development" has become central in education, driven by rapid technological advancement (Bax et al., 2024; Butcher & Ferguson, 2023; Kirchhoff, 2022). Literature highlights the urgent need for curriculum redesign to equip students with essential digital skills (Beerkens, 2022; Peters & Thon, 2024; Schumacher et al., 2022). Mielikäinen and Viippola (2023) found project-based learning in digital environments improved ICT engineering students' experiences but noted challenges with social interaction and practical application. Sinervo et al. (2023) stress that public financial managers require broader skills to navigate digitalisation and e-government, necessitating curricula that reflect modern professional realities. According to Klopov et al. (2023), the development of a cognitive model of education in artificial intelligence is essential for enhancing digital competencies.

Adaptability and resilience were also crucial, especially post-COVID-19. Shamsudin et al. (2023) reported that although many first-year students appreciated online learning during the pandemic, others struggled due to varied digital readiness. Lucas and Vicente (2023) describe online teaching and learning (OTL) as a "double-edged sword" that offering flexibility but complicating engagement, interaction, and support.

A structured approach is essential for effective digital integration. Shestakova and Morgunov (2023) proposed a framework emphasising infrastructure, organizational backing, and teacher involvement. Pina Stranger et al. (2023) add that evidence-based policies are critical to easing institutional tensions, advocating for a holistic model addressing organizational, pedagogical, and technological dimensions to ensure successful digital transformation. According to Yang et al. (2023), the digital transformation of the working world has posed significant challenges to German vocational education and training, prompting reforms in training regulations and curricula to strengthen industrial adaptability and sustain VET in the digital era.

5.2 Theme 2: Digital Competence and Skills Development

The growing importance of equipping both TVET students and educators with digital competences and skills to navigate the evolving landscape of technical and vocational education has been widely recognised (Pushkarna et al., 2022). Several studies stress the need to embed digital competence into professional training, such as in social work (Taylor-Beswick, 2023), accounting (Arfaoui & Kammoun, 2023), bioeconomy (Zeverte-Rivza et al., 2024) and health sciences (Pramila-Savukoski et al., 2023) where digital tools increasingly influence practical learning outcomes.

In response to the key challenges in developing digital competences among TVET students and educators, particularly in middle-skilled professions, Challenge-Based Learning has emerged as a strategy to connect academic learning with industry-relevant digital challenges (Colombari & Neirotti, 2022). Moreover, studies on vocational teachers (Carlsson & Willermark, 2023) and university

educators (Stare et al., 2023) reveal a sense of uncertainty in adapting to changes, yet also underline the importance of flexible, future-ready teaching approaches.

Developing critical digital competences such as critical thinking and creativity through digital platforms is also emphasised and essential for developing professional competencies (Bidzilya et al., 2022). This includes designing educational quests (Mamaeva et al., 2023), integrating digital literacy for students with disabilities (Ibraimkulov et al., 2022), and applying innovative pedagogical models like DPACK in STEM education (Thyssen et al., 2023).

The role of education in addressing the challenges of building digital competences while simultaneously advancing sustainable development goals is also recognised, with "digitainability" proposed as a concept for inclusive progress (Dovleac et al., 2023). The COVID-19 pandemic accelerated digital transitions, as seen in medical education (Hertling et al., 2022), prompting calls for better infrastructure and training to support both students and lecturers in overcoming barriers to digital skill development in new teaching environments.

Across regions such as Malaysia, Tunisia, Indonesia, and Central Europe, comparative studies reveal variations in readiness and implementation. E-learning initiatives in STEM education (Sukumaran et al., 2023), soft skills development in higher education (Sá & Serpa, 2022) and student preparedness for digital industry demands in TVET (Kuntadi et al., 2022) show that while digitalisation offers great promise, its success hinges on addressing the key challenges faced by students and educators in developing digital competence and skills among TVET students and educators is no longer optional. It is a core component of preparing students and educators for the future of work and sustainable development.

5.3 Theme 3: Digital Inequality and Inclusivity

Digital inequality and inclusivity examined disparities in access, readiness, and outcomes of digitalisation in secondary and higher education. Strielkowski et al. (2022) showed that while top universities leverage digital transformation for competitiveness, less-resourced institutions lag behind. Similarly, Fjeldheim et al. (2024) revealed that students from disadvantaged backgrounds struggle with digital demands in social work education, widening professional readiness gaps.

These challenges intensify in politically or economically unstable countries. In Greece, digital and social inequalities worsened post-pandemic, impacting student engagement (Zaimakis & Kokkinou, 2023). Russian students in 2021 faced major obstacles due to poor internet and digital access (Kalugina & Timchenko, 2023). Ukraine's education reforms aim for digital inclusion yet struggle to ensure equity across regions (Hrynevych et al., 2023).

Inclusive practices also require pedagogical innovation. In Peru, gamification improved reading during the pandemic (Mariella et al., 2022), yet such strategies depend on technology and teacher readiness, which remain inconsistent. These cases stress the need for policies that close infrastructure gaps, enhance digital

literacy, and ensure equity regardless of geography or socioeconomic status. Digitalisation promotes flexible learning, dynamic assessment, and timely feedback.

It also builds 21st-century skills like collaboration and problem-solving. Effective implementation demands infrastructure, pedagogical expertise, and responsible technology use. Developmental models help educators evolve from basic literacy to digital leadership, supporting curriculum and skill reforms (Liu et al., 2024). However, digital inequality remains a barrier. Socioeconomic gaps limit access to devices and connectivity. Bridging this divide requires expanded infrastructure, affordable tech, inclusive training, and gender-sensitive approach (Youssef et al., 2022). These are the key to advancing digital inclusivity.

6. Limitation

This review relied on three major databases which are Scopus, Web of Science, and ERIC. The databases were selected for their robustness, scholarly credibility, and comprehensive coverage of academic literature. Scopus indexes peer-reviewed research across diverse disciplines, Web of Science provides extensive citation data and multidisciplinary content, while ERIC specializes in educational studies. Despite their strengths, these databases are not without limitations. Each varies in terms of scope, indexing criteria, and depth of coverage, which may have resulted in the omission of relevant studies not captured within their collections. Consequently, the findings of this review should be interpreted with the awareness that the evidence base may not be fully comprehensive.

7. Implication

The findings of this study have significant implications for policymakers, educators, and institutional leaders within the TVET ecosystem. The identification of key challenges, particularly in digital transformation, competence development, and inequality, highlights the urgent need for strategic planning, investment in digital infrastructure, and comprehensive capacity-building programs. Educational institutions must also prioritise inclusive policies that ensure equitable access to digital tools and learning opportunities, especially for underserved populations. Moreover, the integration of digital pedagogies should be supported by continuous professional development to empower educators as agents of digital change.

8. Conclusion

This study set out to systematically review the challenges of digitalisation in Technical and Vocational Education and Training (TVET), with the primary objective of identifying critical issues that influence its implementation and effectiveness. The review highlighted three major themes: digital transformation and curriculum development, digital competence and skills development, and digital inequality and inclusivity. Together, these findings underscore the complex and multifaceted nature of digitalisation in TVET, reflecting both opportunities for innovation and barriers that must be addressed to ensure equitable outcomes.

While the study provides valuable insights, its scope was limited to three major databases (Scopus, Web of Science, and ERIC), which may not capture all relevant publications. This limitation should be noted by future researchers, who may expand the coverage by including additional sources or grey literature. Future studies could also investigate empirical evidence at the institutional and policy levels to deepen understanding of how digitalisation strategies are enacted in practice. By addressing these gaps, subsequent research can build upon this review to strengthen digital transformation efforts, inform policymaking, and support more inclusive and sustainable TVET systems.

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