

RESEARCH ARTICLE

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DIGITAL TRANSFORMATION IN TECHNICAL AND VOCATIONAL EDUCATION AND TRAINING (TVET): A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT

Digital transformation has become a strategic imperative for Technical and Vocational Education and Training (TVET) systems as they seek to remain relevant in rapidly evolving digital economies. However, existing research on this topic remains fragmented across technologies, regions, and institutional contexts. This study presents a Systematic Literature Review (SLR) conducted in accordance with the PRISMA guidelines to synthesize current evidence on digital transformation in TVET. A total of 51 peer-reviewed studies published between 2020 and 2025 were selected from five major academic databases and analyzed using a thematic synthesis approach. The review identifies the main digital technologies and information systems adopted in TVET, examines key challenges hindering transformation, explores critical enablers and success factors, and analyzes existing digital transformation frameworks. The findings reveal that while advanced digital technologies such as artificial intelligence, virtual reality, and data-driven systems show strong potential, transformation is predominantly constrained by limited instructor digital pedagogical competence, infrastructure gaps, and weak industry collaboration. Successful digital transformation is consistently associated with strategic governance, industry partnerships, and sustained capacity building. This study provides consolidated insights to support evidence-based decision-making and highlights directions for future research and policy development in TVET digital transformation.



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I. INTRODUCTION

Technical and Vocational Education and Training (TVET) plays a fundamental role in preparing a skilled workforce capable of supporting industrial development and socio-economic growth. Rapid advances in digital technologies have significantly transformed labor market requirements, creating increasing pressure on TVET systems to adapt their educational models, curricula, and delivery mechanisms. In this context, digital transformation emerges as a strategic imperative for maintaining the relevance, effectiveness, and sustainability of vocational education in the digital economy [1], [2]. Recent studies emphasize the growing importance of integrating digital competencies into TVET curricula. The incorporation of digital entrepreneurship skills has been identified as essential for preparing graduates to participate effectively in the digital economy [1]. Similarly, the adoption of Industry 4.0 technologies enhances workforce readiness and technical capability, although challenges related to technology access and institutional capacity persist [3]. Enterprise-TVET partnerships are further recognized as a strategic approach to supporting digital transformation, particularly in developing countries where disparities in resources and infrastructure remain pronounced [2]. Collectively, these studies indicate that continuous adaptation of TVET systems is necessary to meet the demands of a rapidly evolving technological landscape. Digital transformation in TVET extends beyond the adoption of isolated technological tools and represents a comprehensive reconfiguration of vocational education systems.

It involves systematic changes in curriculum design, pedagogical approaches, institutional management, and stakeholder engagement. Hierarchical drivers of digital transformation, including the influence of Industry 4.0 and Industry 5.0 technologies, play a significant role in reshaping TVET systems [4]. The integration of digital pedagogy and educational technologies enables more flexible, industry-aligned, and environmentally oriented training models [5]. In addition, effective implementation of learning management systems requires alignment with vocational pedagogy, adequate digital infrastructure, and continuous professional development for instructors [6]. Emerging technologies such as artificial intelligence, virtual reality, adaptive learning platforms, and data analytics further contribute to enhancing learning flexibility and improving skills alignment in vocational education [7]. Despite these opportunities, the implementation of digital transformation in TVET faces substantial challenges, particularly in developing and transitional economies. Empirical evidence indicates that limited digital infrastructure, insufficient digital competencies among instructors, and financial constraints significantly hinder effective technology integration. For instance, a considerable proportion of TVET institutions experience inadequate infrastructure and low levels of digital skills among trainers [8]. Moreover, digitalisation may exacerbate existing inequalities and introduce challenges related to curriculum design and skill acquisition if not implemented systematically [9]. Additional barriers, including unstable power supply, high costs of digital equipment, and fragmented institutional support, further limit the sustainability of digital transformation initiatives in TVET systems [2].

Although scholarly interest in digital transformation in TVET has increased in recent years, existing research remains fragmented across regions, technologies, and institutional contexts. Many studies focus on individual technologies, isolated case studies, or specific challenges and enablers, while comprehensive syntheses that integrate digital technologies, implementation barriers, enabling factors, and transformation frameworks remain limited. Consequently, there is a lack of consolidated evidence to support informed decision-making and strategic planning for digital transformation in TVET. To address these gaps, this study conducts a Systematic Literature Review (SLR) following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The review systematically analyzes peer-reviewed studies published between 2020 and 2025 with the aim of synthesizing current evidence on digital transformation in TVET. Specifically, this study seeks to: (i) identify the main digital technologies and information systems adopted in TVET, (ii) examine the key challenges hindering digital transformation, (iii) explore the enablers and critical success factors that support successful implementation, and (iv) analyze existing digital transformation frameworks or models proposed for TVET. By achieving these objectives, this study contributes to the advancement of knowledge on TVET digital transformation and provides evidence-based insights for researchers, practitioners, and policymakers.

II. MATERIALS AND METHODS

This study was designed as a Systematic Literature Review (SLR) to synthesize existing research on digital transformation in Technical and Vocational Education and Training (TVET). The SLR methodology was selected to ensure a structured, transparent, and reproducible process for identifying, evaluating, and interpreting all relevant studies on the topic. The review was conducted following the established protocols of the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to maximize rigor and clarity in reporting [10].

II.1 RESEARCH DESIGN AND DATA SOURCES

The review process was structured into distinct phases: identification, screening, eligibility, and inclusion. To capture a comprehensive corpus of literature, the search was executed across five major academic databases: Scopus, Web of Science, ScienceDirect, ERIC, and Google Scholar. These platforms were chosen for their extensive coverage of peer-reviewed journals and conference proceedings in the intersecting fields of education, technology, and vocational training.

II.2 SEARCH STRATEGY AND SELECTION CRITERIA

A systematic and structured search strategy was employed to identify relevant studies addressing digital transformation in Technical and Vocational Education and Training (TVET). Boolean operators were used to combine key search terms, ensuring comprehensive coverage of the research domain. The primary search string applied across all databases was as follows:

“digital transformation” OR “digitalization”) AND (“TVET” OR “technical and vocational education” OR “vocational training”) AND (“digital learning” OR “educational technology” OR “information system”)

The search was restricted to publications published between 2020 and 2025, with the aim of capturing the most recent and relevant developments in the field. Minor adaptations to the search syntax were made where necessary to comply with the specific requirements and indexing rules of each database. To ensure the relevance and methodological quality of the selected studies, explicit inclusion and exclusion criteria were applied. Inclusion criteria comprised: (i) peer-reviewed journal articles and conference proceedings; (ii) publications written in English; (iii) studies focusing on digital transformation or digitalization within a TVET context; and (iv) empirical, conceptual, or systematic review studies. Exclusion criteria included: (i) studies not explicitly related to TVET; (ii) research focusing exclusively on general higher education or K–12 education; (iii) non-peer-reviewed literature such as editorials, book chapters, and reports; and (iv) duplicate publications.

II.3 STUDY SELECTION AND DATA EXTRACTION PROCESS

The study selection process adhered to the PRISMA framework, as illustrated in Figure 1. An initial search yielded 203 records. After removing 47 duplicates, 156 unique studies underwent title and abstract screening. This screening narrowed the pool to 105 studies for a full-text eligibility assessment. Following a detailed review, 51 studies met all criteria and were included in the final synthesis. A structured data extraction form was used to collect consistent information from each included study.

The extracted data comprised: author(s) and publication year; country/region of focus; study type; primary digital technologies discussed; key challenges reported; key enablers or success factors identified; and any digital transformation framework or model proposed. The complete extracted data for all 51 included studies are presented in Appendix A (Table A1).

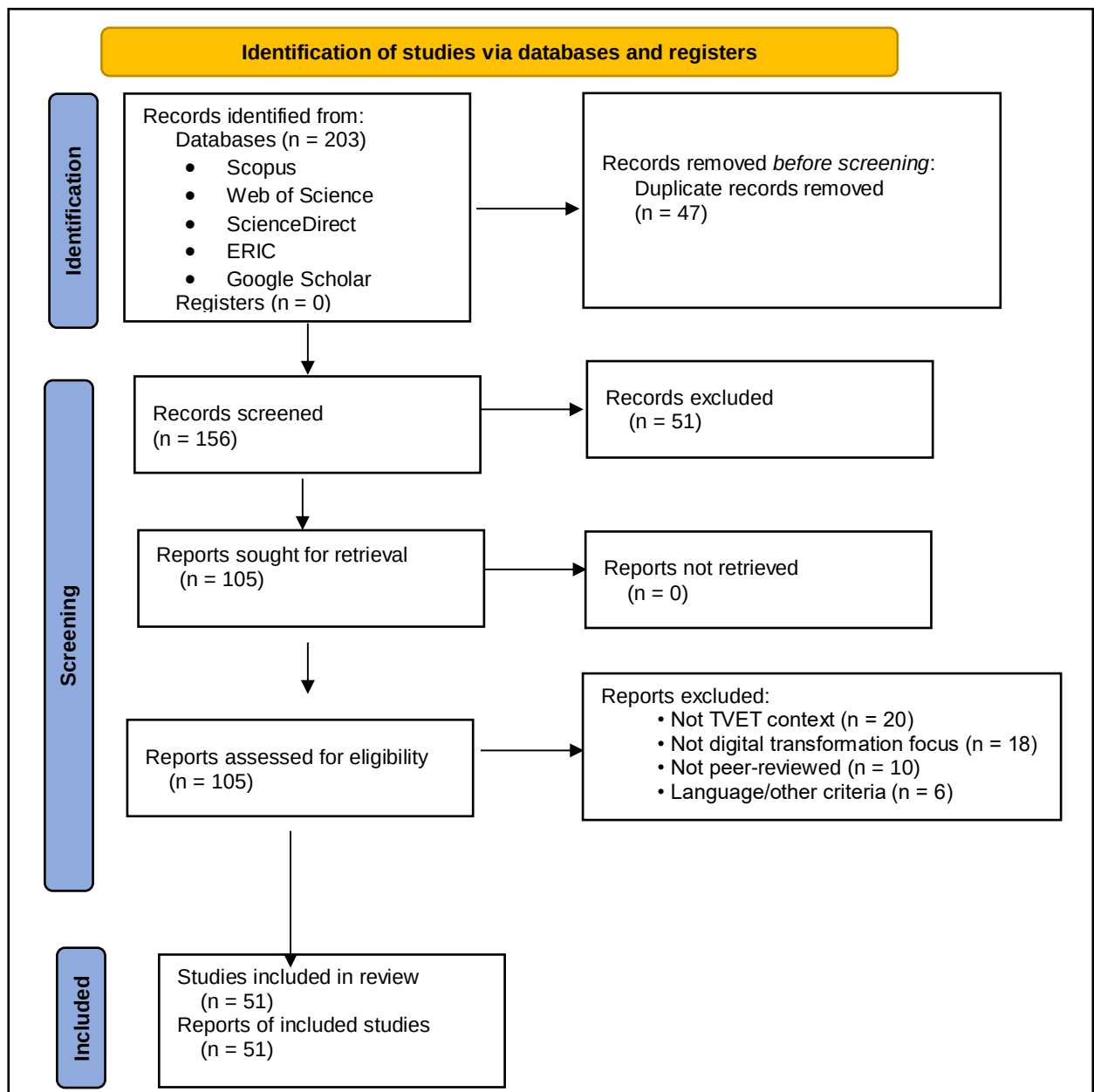


Figure 1: PRISMA flow diagram of the study selection process.

Source: Authors, (2026).

II.4 DATA SYNTHESIS AND ANALYSIS

The extracted data were analyzed using a thematic synthesis approach. Findings from the included studies were systematically coded and organized into emergent thematic categories aligned with the research objectives. These themes included: (i) types of digital technologies adopted in TVET, (ii) barriers to digital transformation, (iii) enabling factors and success conditions, and (iv) proposed digital transformation frameworks. This analytical process facilitated structured comparison across studies, identification of recurring patterns and research gaps, and informed the interpretation of trends discussed in the subsequent results and discussion sections.

III. RESULTS AND DISCUSSIONS

This section presents the findings from a systematic review of 51 peer-reviewed studies published between 2020 and 2025 and discusses their implications for digital transformation in Technical and Vocational Education and Training (TVET). The included studies represent diverse geographical contexts and methodological approaches. The results are synthesized using descriptive and thematic analysis to address the four research objectives, examining trends in digital technologies, key challenges, critical enablers, and proposed transformation frameworks.

A representative overview of the reviewed studies is presented in Table 1, while the complete dataset of all included studies is provided in Appendix A (Table A1). The discussion situates these findings within the broader literature to identify key patterns, research gaps, and implications for policy and practice.

III.1 OVERVIEW OF THE LITERATURE CORPUS

The review comprised 51 studies published between 2020 and 2025. From a geographical perspective, research activity was most prominent in Asia—particularly China and Malaysia—followed by Europe, while Africa and other developing regions were comparatively underrepresented. Methodologically, the corpus was evenly divided between conceptual or review-based studies ($n = 26$) and empirical investigations ($n = 25$), including case studies, survey-based research, and mixed-method designs. This balanced distribution reflects a research field that is simultaneously engaged in theoretical conceptualization and practical validation of digital transformation initiatives in TVET.

III.2 INTEGRATED FINDINGS AND ANALYSIS

The synthesized results for each research objective are presented below, followed by an interpretive discussion that contextualizes them within the broader literature.

III.2.1. Digital Technologies and Information Systems in TVET

The review revealed a stratified adoption of digital technologies in TVET institutions, as summarized in Table 1.

Table 1: Categorization of Digital Technologies in TVET.

Category	Key Technologies	Primary Application/Goal	Exemplary Studies
Foundational Platforms	LMS (Moodle, Canvas), Google Classroom, Google Meet	Content delivery, administration, basic remote instruction.	[11], [12], [13]
Immersive & Simulation Tools	Virtual Reality (VR), Augmented Reality (AR), simulation software (e.g., SinuTrain)	Simulating practical, hazardous, or high-cost tasks in technical fields.	[3], [14], [15]
Advanced & Data-Driven Systems	Artificial Intelligence (AI), Internet of Things (IoT), Big Data Analytics, Blockchain	Personalized learning, smart workshops, skills gap analysis, credentialing.	[16-19]
Enabling Infrastructure	"Cloud-edge-device" ecosystems, Enterprise Architecture (EA), multifunctional platforms	System integration, data-informed management, and scalable service delivery.	[20-22]

Source: Authors, (2026).

The findings reveal a trajectory from digitizing existing processes (e.g., using LMS for document sharing) toward transformative applications that alter teaching and learning fundamentally (e.g., AI-driven personalized pathways). However, a significant gap persists between the availability of advanced technologies and their deep pedagogical integration. While VR/AR shows strong promise for vocational skills acquisition [15], its use remains limited by cost and instructor know-how, underscoring that technological potential is necessary but insufficient for transformation [7].

III.2.2. Key Challenges Hindering Digital Transformation

Challenges were pervasive and interconnected, forming a barrier ecosystem. The most frequently cited are ranked in Figure 2.

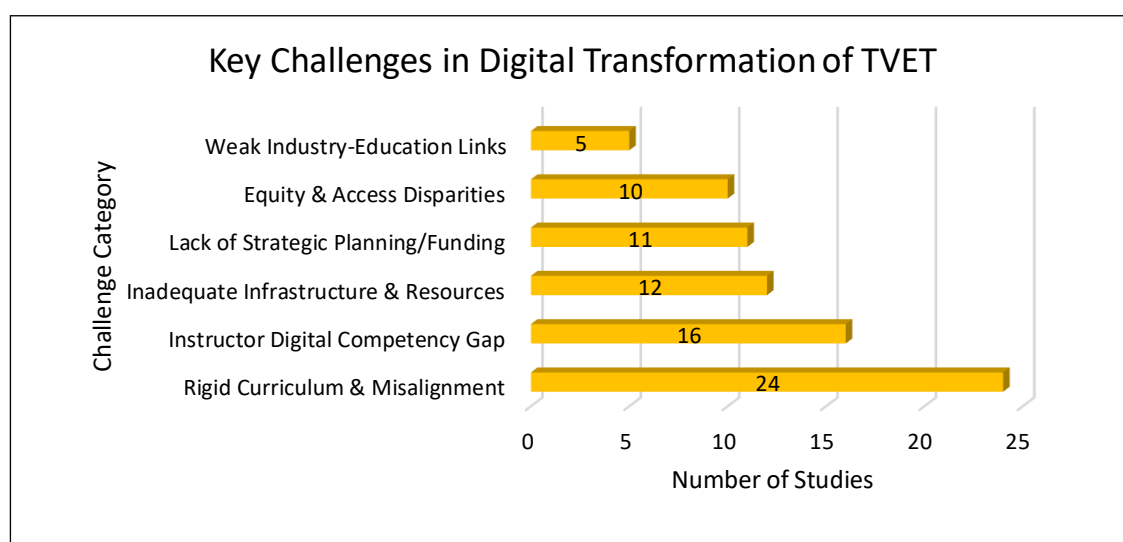


Figure 2: Prevalence of Major Digital Transformation Challenges in TVET Literature.

Source: Authors, (2026).

The centrality of the human factor—specifically, instructors' digital pedagogical competence—emerges as the foremost bottleneck. This finding confirms and extends prior concerns [6], [8], indicating that even with adequate infrastructure, transformation stalls without skilled educators. Furthermore, challenges are systemic; for example, "Rigid Curriculum" [9], [23] is compounded by "Weak Industry-Education Links" [16]. This interconnectivity explains the failure of siloed interventions and highlights the need for holistic strategies that address multiple barriers simultaneously, particularly in resource-constrained contexts [2].

III.2.3. Enablers and Critical Success Factors

Effective digital transformation was consistently associated with a combination of strategic, collaborative, and human-centric enablers, as synthesized in Table 2.

Table 2: Critical Success Factors for TVET Digital Transformation.

Factor Category	Key Elements	Impact/Outcome	Exemplary Studies
Governance & Strategy	National policy support, institutional leadership commitment, dedicated funding models.	Creates a supportive mandate and enables resource allocation.	[24], [20], [25], [26]
Partnerships & Ecosystems	Deep collaboration with industry, engagement with all stakeholders (students, staff), cross-institutional networks.	Ensures relevance, provides resources (tech, expertise), and aligns training with market needs.	[16], [27-30]
Capacity Building	Continuous professional development for instructors focused on pedagogical integration (TPACK), instructional design support.	Bridges the digital pedagogy gap, empowering educators as change agents.	[31-34]
Implementation Approach	Phased, pedagogy-first adoption, piloting, and context-sensitive design.	Increases sustainability, reduces resistance, and ensures solutions address real pedagogical problems.	[31], [20], [35]

Source: Authors, (2026).

The synergy between these factors is paramount. A national policy (Governance) can incentivize industry partnerships, which then inform relevant professional development (Capacity Building). Notably, successful enablers move beyond mere technology training for educators towards developing their instructional design capability for digital environments [33], aligning with calls for a paradigm shift in teaching roles [5]. This underscores that enablers must target the transformation of teaching and learning processes, not just the introduction of tools.

III.2.4. Digital Transformation Frameworks and Models

Analysis of 30 frameworks revealed an evolution from component-based lists to dynamic, systemic models. A typology is presented in Table 3.

Table 3: Typology of Digital Transformation Frameworks in TVET.

Framework Type	Core Logic	Typical Components	Exemplary Studies
Multi-Pillar Structural	Transformation is achieved by strengthening key institutional pillars.	Policy, Infrastructure, People, Curriculum, Partnerships.	[27], [36], [22]
Process & Driver-Oriented	Transformation is a dynamic process responding to internal/external drivers.	Needs assessment, implementation phases, feedback loops, drivers (e.g., Industry 4.0, sustainability).	[4], [23], [17]
Theory-Grounded	Transformation is guided by an overarching pedagogical or organizational theory.	TPACK model, Socio-Technical Systems, Didactic Systems Theory, People-Process-Technology.	[28], [37], [18], [34]

Source: Authors, (2026).

The progression towards process-oriented and theory-grounded frameworks represents a significant maturation in the field. It moves the focus from "what" needs to be in place to "how" change can be managed and sustained. Frameworks emphasizing inclusivity [28] and crisis adaptation [12] are particularly innovative, addressing urgent societal and contextual needs. However, a key limitation persists: most frameworks are descriptive or prescriptive rather than being validated through longitudinal application. This gap points to a critical area for future research—testing and refining these models in diverse TVET contexts to develop robust, evidence-based implementation roadmaps.

III.3. SYNTHESIS AND IMPLICATIONS

The integrated findings lead to two overarching conclusions. First, digital transformation in TVET is fundamentally a pedagogical and institutional change process, with technology serving as an enabler rather than a driver. The persistent gap in instructors' digital pedagogical competence represents the most influential leverage point for sustainable transformation. Second, successful transformation requires systemic alignment among strategic vision, partnership ecosystems, capacity-building mechanisms, and iterative implementation approaches.

From a practical perspective, these findings suggest the need to rebalance investment priorities toward sustained professional development for educators and the strengthening of industry–education partnerships. For future research, greater emphasis should be placed on developing context-adaptive implementation tools and conducting longitudinal studies to empirically validate digital transformation frameworks across diverse TVET settings.

IV. CONCLUSIONS

This systematic literature review synthesized evidence from 51 peer-reviewed studies published between 2020 and 2025 to provide a comprehensive understanding of digital transformation in Technical and Vocational Education and Training (TVET). The findings demonstrate that digital transformation in TVET extends beyond the adoption of isolated technologies and represents a systemic pedagogical and institutional change process. While a wide range of digital technologies—from foundational learning management systems to advanced AI- and data-driven solutions—are increasingly adopted, their transformative impact remains constrained by persistent challenges, particularly limited instructor digital pedagogical competence, inadequate infrastructure, rigid curricula, and weak industry–education linkages. The review further identifies that successful digital transformation is consistently enabled by the alignment of strategic governance, strong industry partnerships, sustained capacity building for educators, and phased, pedagogy-first implementation approaches. Moreover, the analysis of existing transformation frameworks reveals a gradual shift toward process-oriented and theory-grounded models, although empirical validation of these frameworks remains limited. Overall, this study contributes consolidated evidence to an otherwise fragmented research field and offers actionable insights for policymakers, institutional leaders, and researchers. Future research should prioritize longitudinal validation of transformation frameworks and the development of context-sensitive implementation roadmaps, particularly for resource-constrained TVET systems.

V. AUTHOR'S CONTRIBUTION

Conceptualization: Hadi Almohab and Deden Witasryah.

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Search strategy and study selection: Mohd Farhan Bin MD. Fudzee and Hadi Almohab

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Supervision: Deden Witasryah and Mohd Farhan Bin MD. Fudzee

Approval of the final text: Deden Witasryah.

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APPENDIX A: SUMMARY OF 51 INCLUDED STUDIES IN THE SYSTEMATIC REVIEW

Table A1: Characteristics and Key Findings of Included Studies (2020-2025).

ID	Author(s) [Ref]	Year	Region	Study Type	Focus	Key Challenges	Key Enablers	Framework/Mo del
1	Rajamanickam et al. [3]	2024	Malaysia	SLR	TVET with IR 4.0	Access disparities, implementation barriers, regional inequality	VR/AR simulation, big data, AI & IoT	3-phase SLR methodology
2	Othman et al. [9]	2025	Malaysia	SLR	TVET digitalisation	Curriculum alignment, educator competence, digital inequality	Flexible learning, industry training, inclusive practices	SLR on curriculum/skills/ inclusivity
3	Parua & Yang [4]	2024	China	Review/Conceptual	Driving logic of DT	Aligning with Industry 4.0/5.0, sustainability, employment	Digital tech, policy frameworks, sustainability initiatives	Hierarchical driving logic framework
4	Anisimova & Efremova [38]	2021	Russia	Conceptual/Review	DT of vocational education	Socio-economic change, outdated curricula	Digital tools, paradigm shift	Conceptual directions
5	Kovalchuk et al. [39]	2022	Ukraine	Conceptual/Problem analysis	DT of vocational schools	Infrastructure limits, teacher competence, COVID-19	Digital equipment, upskilling, blended learning	Problem-analysis framework
6	Han et al. [40]	2023	China	Conceptual/Review	DT in vocational education	Student learning, IT integration, teacher proficiency	National policies, strategic view, rational approach	Ideas and strategies
7	Xu et al. [31]	2024	China	Conceptual/Experience	DT of vocational education	Tech-human balance, R&D integration, governance	Digital empowerment, platform building, participatory approaches	Human-oriented participatory framework
8	Wang [27]	2024	China	Conceptual/Review	DT of vocational education	Resource distribution, industry disconnect, teacher literacy	Government policy, enterprise collaboration, school efforts	4D pathway framework
9	Herrero et al. [41]	2025	EU	Conceptual/Policy	DT of VET	Skills gap, labor market needs, SME adoption	EU initiatives, SELFIE tool, VET-company collaboration	Policy-informed framework
10	Zhu et al. [42]	2023	China	Conceptual/Experimental	DT of vocational education	Infrastructure, pedagogical training, data protection	ICT integration, big data analytics	Experimental curriculum model
11	Herrero Rámila et al. [28]	2025	EU	Conceptual/Framework	Inclusive DT of European VET	Technical focus only, lacks holistic approach	Socio-technical systems, collaboration	8-element inclusive framework
12	Alyokhina et al. [37]	2025	Russia	Conceptual/Methodological	DT in vocational / technical ed	Adapting under sanctions, training personnel	Didactic systems theory, digital tech	Model didactic system
13	Dwiyanti & Sari [11]	2021	Indonesia	Empirical/Quantitative	DT during COVID-19	Practical adaptation, internet access	Multiple platforms, Google tools	Survey-based platform selection
14	Rujira et al. [36]	2020	Thailand	Conceptual/Framework	DT in vocational colleges	Aligning operations, workforce demands	Policy, Process, People, Stakeholders, Infrastructure	5-pillar transformation framework
15	Leong [43]	2021	Austria	Conceptual/Literature	DT in vocational/business ed	Adapting to digital skills, teacher development	Literature insights, staff development	Conceptual design guidance
16	Xie & Zhang [16]	2025	Malaysia	Conceptual/Conference	AI integration in TVET	Digital divide, instructor capabilities	AI tools, virtual simulation, partnerships	Strategic policy frameworks
17	Xie & Zhang [44]	2023	Global	Bibliometric/Review	Global trends in DT	Uneven research, sustainability needs	Data-driven insights, industry integration	Visualization & guidance
18	Rauseo et al. [41]	2022	Switzerland	Empirical/Original	DT in Swiss vocational schools	Communication gaps, competency perceptions	Stakeholder inclusion, assessment	Assessment framework
19	Zhang [20]	2025	China	Empirical/Conceptual	DT in vocational education	Tech outpacing educators, policy gaps	Cloud-edge ecosystems, digital certification	5D framework

20	Wang [45]	2024	China	Theoretical/ Conceptual	DT in vocational education	Tech integration, teacher literacy	Digital platforms, training, policy support	Theoretical strategies framework
21	Kovalchuk et al. [12]	2024	Ukraine	Conceptual/ Empirical	DT under crisis conditions	Crisis training, digital literacy, access	Online/blended learning, cooperation	Digital literacy emphasis
22	Ma et al. [25]	2025	China	Case Study/Empiri- cal	DT in vocational colleges	Policy-infrastructure alignment, competencies	Policy support, infrastructure, training	Best practices pathways
23	Nazarova et al. [14]	2021	Russia	Case Study/Empiri- cal	DT in practical training	Practical adaptation, collaboration	Network interaction, VR/AR, dual education	Dual education system
24	Zhang [23]	2025	China	Empirical/Mi- xed-Methods	DT of practical modules	Rigid design, outdated methods, weak links	Module reconstruction, innovation	Dynamic reconstruction path
25	Zhao & Han [15]	2024	China	Empirical/Ca- se-based	Curriculum reform with VR/AI	High costs, instructor training	Industry collaboration, feedback	Curriculum reform strategies
26	Harder & Schumann [26]	2025	Switzerlan- d	Empirical/Su- rvey	Leadership impact in vocational schools	Regional differences, financial variability	Innovative leadership, policy measures	Leadership profiles for sustainable integration
27	Yang & Wu [29]	2024	Internation- al	Case study/Thema- tic	International cooperation in TVET	Digital disparities, sustainability issues	Global dialogue, OER, capacity building, partnerships	Four-approach framework
28	Xia et al. [17]	2025	China	Conceptual/ Reform	IoT-empowered teaching reform	Structural curriculum challenges, industrial needs	Collaborative teams, modular materials, blended teaching	Paradigm reconstruction & mechanism innovation
29	Kulynych [46]	2021	Ukraine	Review/Con- ceptual	DT of vocational institutions	Digital literacy gaps, systemic challenges	SELFIE platform, EU best practices, Erasmus+	Four vectors of digital development
30	Mirzaeva et al. [35]	2025	Uzbekistan	Mixed- methods	Role of digital tech (e-learning, VR)	Infrastructure, educator readiness, policy gaps	Infrastructure investment, teacher training, PPPs	Empirical assessment model
31	Tan [47]	2025	China	Case study/Practic- e	AI-supported DT with ideological education	Aligning AI with objectives, culture-tech balance	AI for Five- Education Integration	AI + Ideological Education model
32	Zeng et al. [48]	2024	China/Mal- aysia	Conceptual/ Curriculum	Entrepreneurship education in TVET	Curriculum alignment, entrepreneurship integration	Literature framework, course analysis	Vial-based curriculum framework
33	Schröder & Dehnbostel [30]	2021	Germany	Conceptual/ Theoretical	DT via work-based learning	Workplace learning quality, task- competence alignment	Work digitalization, improved organization, training personnel	WBL models emphasizing workplace proximity
34	Zhang & Zhang [49]	2025	China	Empirical/Su- rvey-Case	Digital learning competencies in HVIIs	Proficiency disparities, skill gaps	Curriculum redesign, pedagogy, resources, tech	Multifaceted integration approach
35	Xu [50]	2023	China	Conceptual/ Applied	Teaching mode adaptation	Teaching mode transformation, tool adaptation	Diverse resources, personalized learning, interactive environment	Integrated teaching mode
36	Demartini et al. [32]	2024	Italy	Applied project/Case	DT for teacher/institutiona- l upskilling	Scaling competence, stakeholder alignment, systemic issues	Cascade training, partnerships, learning ecosystem	Riconnessioni project framework
37	Cañavate- Cruzado et al. [51]	2020	Europe	Project/Appli- ed	KETs in VET, digital skills for SSH	ICT skill gaps, innovation translation, Valley of Death	IoToAI project, foresight, KET curriculum	IoToAI project framework
38	Yang [52]	2024	China	Conceptual/ Applied	Training management integration with DT	Faculty development, tech upgrades, resistance	Personalized learning, collaboration, resource-sharing, AI assessments	Strategies for integration
39	Jiang et al. [18]	2024	Internation- al	SLR Mapping	Digital tech applications in teaching	Low research maturity, innovation lack, optimization limits	Cross-fertilization, PPT theory	PPT theory & CMM
40	Findeisen & Wild [53]	2022	Germany	Empirical/Su- rvey	Digital competences of trainees in commercial VET	Skill differences, certificate influence, limited exposure	Private digital activities, competence profiles	Competence profiling

41	Wintersberg & Pittich [33]	2025	Germany	Qualitative case study	DT of corporate technical education	Communication gaps, instructional design, job role clarity, target group attitudes	L&D support, best practices, structured design processes	Episodic narrative interviews
42	He [54]	2025	China	Practice-based teaching	DT of English teaching in higher vocational education	Low teacher digital skills and engagement.	Multimodal resources, systematic approach, digital standards, optimized design	Multimodal teaching system
43	Holler et al. [34]	2023	South Africa	Empirical survey (quant+qual)	Digital competencies of TVET lecturers	Gaps in tech-enhanced lesson planning, content creation skills, TPACK variance	Targeted training, professional development, lesson planning support	TPACK model
44	Yang et al. [55]	2023	Germany	Conceptual & content analysis	DT of VET, sustainability in training	Insufficient service capacity, decreasing attractiveness, low digital competence application	Modernized curricula, financial incentives, digital skills development, policy support	Sustainability framework (capability, attractiveness, adaptability)
45	Truong & Diep [56]	2024	Global	Literature review/Thematic	DT in tertiary education, tech trends	Integration challenges, traditional method adjustment, research gaps	AI, IoT, Blockchain, VR/AR, Big Data, Cloud, RPA, mobile & social platforms	PRISMA-based thematic analysis
46	Lin & Pang [57]	2024	China	Case study	DT in TVET program development	Adapting to labor market, lack of practical DT research	Institutional strategies, program planning, ecosystem development	In-depth case analysis (Shenzhen Polytechnic)
47	Ning Zhang [19]	2025	China	Conceptual/ Applied research	AI-enhanced multimodal pedagogy	Low personalization, low interactivity in traditional teaching	AI techniques (ML, NLP), multimodal data, personalized plans, real-time feedback.	Multimodal data-driven teaching model
48	Razak et al. [13]	2025	Malaysia	Empirical/Survey	Digital learning in TVET	Practicality of TVET online, infrastructure needs	Faculty readiness, lecturers' digital knowledge, infrastructure support	Preliminary framework development
49	Rêgo et al. [58]	2023	International	SLR	DT, skills, education	Skills gap, workforce readiness, curriculum misalignment	Digital literacy, reskilling, learning models	Seven-category framework
50	Yujie et al. [21]	2025	China (Guangdong)	Mixed-methods	DT of educational management	Administrative centralization, infrastructure lack, uneven teaching quality	Digital tools & infrastructure, multifunctional platform, data-driven decisions	Three-component framework (teacher, teaching, student management)
51	Hussein et al. [22]	2024	Malaysia/F inland	Mixed-methods (SLR+interviews)	Enterprise Architecture for TVET DT	Management involvement, goal alignment with industry, emerging tech integration	Management support, clear vision, AI & IoT adoption	EA framework for sustainable DT

Source: Authors, (2026).

Note: DT = Digital Transformation; TVET = Technical and Vocational Education and Training; VET = Vocational Education and Training; SLR = Systematic Literature Review; IR 4.0 = Industry 4.0; AI = Artificial Intelligence; IoT = Internet of Things; VR/AR = Virtual/Augmented Reality; ICT = Information and Communication Technology; EU = European Union; L&D = Learning and Development; TPACK = Technological Pedagogical Content Knowledge; ML = Machine Learning; NLP = Natural Language Processing; RPA = Robotic Process Automation; EA = Enterprise Architecture; OER = Open Educational Resources; PPP = Public–Private Partnership; WBL = Work-Based Learning; KET = Key Enabling Technologies; SSH = Social Sciences and Humanities; HVI = Higher Vocational Institutions; PPT = People–Process–Technology; CMM = Capability Maturity Model.