



Digital Transformation, Artificial Intelligence, and Career Development in Vocational Technology Education: An Integrative Review Based on Twenty Articles and VOSviewer Mapping

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ARTICLE INFO

Article history:

Received: July, 2026

Received in revised from:
Agustus, 2026

Accepted: September, 2026

Available online: September, 28,
2026

Keywords:

Vocational Technology
Education, TVET, Artificial
Intelligence, Career
Development, Digital
Competence

ABSTRACT

Digital Transformation, Artificial Intelligence, and Career Development in Vocational Technology Education: An Integrative Review Based on Twenty Articles and VOSviewer Mapping. This article synthesizes twenty uploaded scholarly documents to examine how digital transformation, artificial intelligence (AI), Industry 4.0/5.0, and learning technologies reshape career development in Vocational Technology Education (VTE) and Technical and Vocational Education and Training (TVET). Using an integrative literature review supported by VOSviewer-based visual interpretation, the study reorganizes findings from diverse contexts into a career-oriented conceptual framework. The analysis identifies career development as the central connecting theme linking AI adoption, digital competence, e-learning, electronic portfolio management, cybersecurity behavior, hard skills, lifelong learning, and industry-responsive curricula. The findings show that technology integration in VTE is not merely a matter of introducing digital tools. It requires a systemic alignment of teacher competence, curriculum relevance, institutional governance, industry collaboration, data-informed learning ecosystems, and sustainable lifelong learning pathways. AI can strengthen personalization, feedback, assessment, and instructional efficiency; however, its educational value depends on pedagogical judgment, ethical data practices, infrastructure, and professional development. This study proposes an integrative TVET 5.0 framework built on five pillars: human-centered AI, teachers' digital and AI competence, industry-responsive curriculum, secure and inclusive technology governance, and lifelong career development ecosystems. The article contributes a synthesized scholarly argument for designing VTE curricula that improve employability, adaptability, and career resilience in the era of intelligent and sustainable industry.

1. Introduction

Vocational Technology Education has entered a period in which career preparation can no longer be separated from digital transformation (López et al., 2023). The emergence of artificial intelligence,

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<https://doi.org/10.56806/jh.v7i3.458>

automation, the Internet of Things, data analytics, electronic portfolios, cybersecurity practices, and smart industrial systems has changed the meaning of vocational competence(Suharno et al., 2025). Graduates are expected not only to master occupational skills but also to navigate digital tools, interpret data, solve unfamiliar problems, collaborate with intelligent systems, and continuously renew their expertise throughout their working lives(Habibi et al., 2023).

The reviewed literature indicates that TVET is increasingly positioned as a strategic bridge between technological change and human capital development(Bruri Triyono & Hariyanto, 2024). In several national contexts, TVET is expected to reduce skills mismatch, strengthen employability, and support inclusive economic development(Kuntadi et al., 2022). However, the same literature also shows that vocational institutions often struggle to keep pace with industrial transformation(Tanggu Mara et al., 2025). Limited infrastructure, uneven teacher competence, curriculum rigidity, weak industry linkages, and insufficient governance of digital systems can prevent technology from becoming a meaningful educational resource(Alamsyah et al., 2022).

A central issue emerging from the synthesis is career development. The VOSviewer map included in this study places career development at the core of the keyword network, suggesting that AI, digital competence, lifelong learning, e-learning, electronic portfolio management, hard skills, capability development, and cybersecurity behavior are not isolated topics(McAllister et al., 2022). They represent different pathways through which vocational education can enhance learners' career readiness and long-term employability(Moh & Mufti, 2022). In this sense, digital transformation should be understood as an ecosystem for career formation rather than as a simple technological upgrade(Mann et al., 2022).

This article translates and reorganizes the Indonesian manuscript into an English academic article using the journal template while maintaining the original author and affiliation information. The narrative is deliberately rewritten rather than directly translated word by word, so that the argument becomes clearer, more coherent, and more suitable for scholarly publication. The article aims to answer three questions: (1) what major themes arise from the twenty reviewed documents; (2) how do these themes clarify the relationship between digital transformation and career development in VTE; and (3) what conceptual framework can be proposed for strengthening TVET in the era of AI, Industry 5.0, and lifelong career development.

2. Methodology

This study employed an integrative literature review design. This approach was selected because the reviewed documents used diverse methodologies, including systematic reviews, bibliometric or scientometric analyses, quantitative models, qualitative inquiry, mixed methods, instrument validation, econometric analysis, and conceptual review. Rather than conducting a statistical meta-analysis, the study synthesizes conceptual patterns across studies and develops a coherent interpretation of how digital transformation affects career-oriented vocational education.

The source material consisted of twenty uploaded article documents. During the screening process, two documents were found to contain the same study on educational interventions and the digital divide in Ghana. Therefore, the analysis retained the full set of twenty documents for transparency but treated the duplicated study as one bibliographic reference in the final reference list. The reviewed studies cover AI adoption in TVET, AI skills in construction, STEM prediction, large-scale educational assessment, manpower development, lifelong learning in engineering, e-learning, electronic portfolio systems, Education/Industry/Work 5.0, Employment 5.0, smart supply chain barriers, teachers' digital competence, 4IR implications for TVET, AI-TPACK, user-generated content, cybersecurity, operations management competence, and knowledge alliance in aviation(Desky et al.,

2026). The analytical procedure involved four stages. First, the documents were mapped by topic, context, method, and contribution. Second, repeated concepts were grouped into thematic categories. Third, closely related categories were consolidated into broader synthesis dimensions. Fourth, the VOSviewer figure was interpreted as a visual support for identifying the most central and connected themes. The resulting synthesis was then rewritten into a new English narrative with in-text references to preserve academic integrity and avoid unattributed textual borrowing.

3. Results and Discussion

The visual map provides an important entry point for interpreting the twenty documents. Career development appears as the largest and most central node, while related nodes include artificial intelligence, digital competence, vocational education, e-learning, electronic portfolio management, cybersecurity behavior, lifelong learning, hard skills, competence, capability approach, and fourth industrial revolution. This configuration indicates that career development functions as a conceptual bridge connecting technology, pedagogy, skills, institutional readiness, and future work.

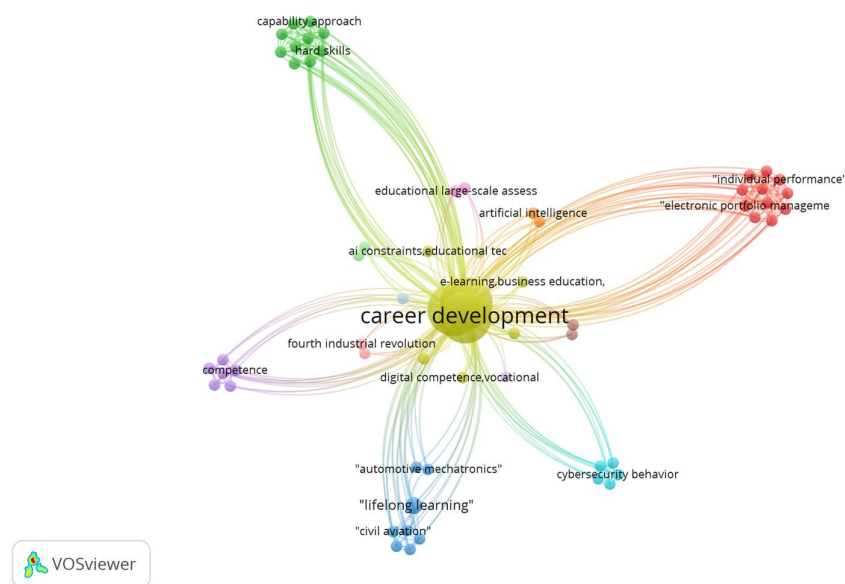


Fig 1. VOSviewer map showing career development as the central theme in the reviewed literature.

The map sharpens the interpretation of the review. The first cluster links AI, educational technology, and e-learning, emphasizing technology as an instructional enabler. The second cluster connects digital competence, vocational education, and the fourth industrial revolution, pointing to teacher readiness and curriculum renewal. The third cluster links lifelong learning, automotive mechatronics, and civil aviation, reflecting the importance of modular learning and industry-based knowledge alliances. The fourth cluster includes electronic portfolio management and individual performance, highlighting the need for evidence-based assessment of competence. The cybersecurity cluster reminds vocational institutions that digital learning environments must also be safe, responsible, and resilient.

Table 1. Thematic synthesis of the reviewed documents

Theme	Supporting Sources	Synthesis Focus
AI adoption and teacher readiness	(Aziz et al., 2026)	AI strengthens learning only when teachers possess adequate technological, pedagogical, ethical, and content-specific competence.
Digital learning ecosystem	(Zielińska et al., 2026)	E-learning, educational data, e-portfolios, and user-generated content expand learning opportunities and evidence-based assessment.
Industry 4.0/5.0 and future work	(Parua & Yang, 2024)	Vocational education must prepare learners for human-AI collaboration, sustainability, transversal competence, and changing occupational structures.
Lifelong learning and industry partnership	(Nthako & Khumalo, 2025)	Modular programs and knowledge alliances connect education with emerging occupational standards and professional reskilling needs.
Governance, security, and infrastructure	(Abd Rahman et al., 2025)	Digital transformation requires policy support, infrastructure, cybersecurity awareness, analytics capacity, and coordinated institutional governance.

3.1 From Skill Training to Career-Oriented Competency Ecosystems

The synthesis indicates that TVET is moving from a narrow training model toward a broader competency ecosystem. Traditional vocational education has often been associated with job-specific technical preparation. The reviewed studies, however, show that current and future work requires a more complex combination of technical expertise, digital competence, problem-solving, communication, adaptability, and sustainability awareness. This shift is essential because careers are no longer stable linear pathways; they are increasingly shaped by technological disruption, industry reconfiguration, and recurring demands for reskilling.

The Ethiopian TVET study illustrates both the promise and the limitations of vocational programs. Although TVET can improve access to economic opportunity, the effectiveness of such programs is weakened when graduates do not obtain competencies that match labor market expectations [6]. Similarly, the South African study on 4IR and TVET stresses that curricula, lecturer capacity, practical learning environments, and industry collaboration must be strengthened to prevent graduates from entering the labor market with outdated skills(Tekle et al., 2024).

Career development therefore becomes a useful organizing lens. It shifts the focus from whether learners acquire isolated skills to whether the education system enables them to build durable capabilities, employment readiness, mobility, and long-term adaptability. The capability approach and hard skills cluster in the VOSviewer map supports this argument: vocational graduates require both occupational competence and the broader agency to use their knowledge in changing work environments.

3.2 Artificial Intelligence and the Repositioning of Vocational Pedagogy

AI is one of the strongest themes in the reviewed studies. It appears as a tool for instructional preparation, personalized learning, feedback, assessment, content development, and decision support. Nevertheless, AI should not be framed as a replacement for vocational educators. Its most

productive role is to augment teachers' professional judgment and support learning activities that are difficult to manage through traditional instruction alone (EDO & EDO, 2025).

Omeh's study on TVET lecturers indicates that AI adoption may support students' self-efficacy when lecturers use it to create structured learning experiences, improve feedback, and connect learning tasks with workplace relevance. However, the same study highlights constraints related to infrastructure, institutional support, cost, pedagogical adaptation, and psychological strain. These findings suggest that the success of AI integration depends as much on organizational and pedagogical conditions as on the availability of the technology itself.

The construction-focused review by Obi et al. shows that AI skills include data literacy, machine learning fundamentals, programming, digital collaboration, AI-assisted decision-making, cybersecurity awareness, change management, and communication [3]. Although the study focuses on construction professionals, the skill domains are relevant to many vocational fields. They indicate that AI literacy in vocational education should be interdisciplinary: learners need technical understanding, but they also need judgment, adaptability, and collaboration.

3.3 Teachers' Digital Competence and AI-TPACK

Teachers remain the decisive factor in digital transformation. The Indonesian study on vocational teachers' digital competence shows that low competence is shaped by both external and internal factors. External barriers include limited internet access, inadequate hardware, insufficient training, and weak professional support communities. Internal barriers include low confidence, age-related beliefs, and preference for familiar traditional methods. These findings are important because they challenge the assumption that digital transformation can be achieved simply through technology procurement (Setiyawan et al., 2025). The AI-TPACK validation study offers a more precise way to understand teacher readiness. It argues that vocational teachers need an integrated knowledge base combining AI-related technological knowledge, pedagogical knowledge, content knowledge, and their intersections. This is especially relevant in vocational settings because the use of technology must be connected to domain-specific practices. For example, AI in engineering drawing, automotive simulation, electrical systems, or digital manufacturing requires pedagogical decisions that differ from general classroom technology use.

A career-oriented TVET curriculum should therefore include systematic professional development for teachers. Training should not be generic or one-time. It should be contextual, discipline-specific, project-based, and connected with real workplace technologies. AI-TPACK can be used diagnostically to identify whether teachers need support in tool operation, instructional design, content integration, assessment, or ethical data use.

3.4 Industry-Responsive Curriculum and Lifelong Learning

The reviewed studies consistently emphasize the need for stronger alignment between curriculum and industry transformation. Education and digitalization may both support economic development, but their interaction can be weak or even counterproductive when educational content does not correspond to the competencies required in the digital economy. This point is particularly relevant for developing countries, where investment in digital infrastructure may not automatically produce productivity gains unless the workforce has sufficient absorptive capacity (Caraig, 2026).

Lifelong learning appears as another key theme. The modular TVET program in the automotive sector demonstrates how professional education can support engineers and technicians facing green and digital transitions. Similarly, the aviation knowledge alliance study shows that curriculum development can be strengthened through structured collaboration between universities, industry partners, and qualification frameworks. These studies suggest that vocational curricula should not be static documents. They should be living systems updated through labor market analysis, industry consultation, and professional feedback.

For VTE, this means that AI, IoT, e-portfolios, cybersecurity, simulation, and smart systems should not be added as isolated topics. They need to be embedded into learning outcomes, laboratory activities, projects, assessment rubrics, internships, and industry-based learning experiences. Such integration supports not only immediate employment but also lifelong career development.

3.5 Digital Learning Ecosystems: E-Learning, E-Portfolios, UGC, and Educational Data

A digital learning ecosystem is more than a learning management system. It consists of online resources, curricula, portfolios, user-generated content, analytics, assessment tools, and institutional policies that support learning continuity. The study on e-learning resources in business education shows that online libraries and online curricula significantly support content delivery. This finding reinforces the view that access to updated digital learning materials can strengthen instructional effectiveness and learner autonomy.

Electronic portfolio management is especially important for vocational education because vocational competence must be demonstrated through evidence. E-portfolios can record projects, practical performance, reflections, and learning outcomes, making competence more visible to teachers, institutions, and potential employers. However, successful adoption depends on technological quality, organizational support, training, finance, cloud readiness, and government roles.

User-generated content also has potential for TVET. Technical tutorials, demonstration videos, workshop documentation, peer explanations, and practitioner-generated materials can expand the learning ecosystem beyond the formal classroom. Yet UGC must be governed carefully because open content may vary in accuracy, safety, and relevance. Vocational educators and industry practitioners should be encouraged to contribute high-quality content to strengthen the TVET knowledge ecosystem. Educational data offers another promising direction. Studies on STEM prediction and large-scale longitudinal assessment show that data can help institutions understand students' choices, competence development, educational inequality, and school-to-work transitions. However, data-based decision-making must be accompanied by strong attention to privacy, bias, validity, and responsible interpretation.

3.6 Cybersecurity, Smart Systems, and Digital Governance

The expansion of digital learning introduces new risks. Cybersecurity policies, user behavior, and technological readiness influence institutional security performance in remote learning environments. TVET institutions are particularly exposed because they manage student records, learning platforms, workshop data, digital portfolios, technical designs, and sometimes industry-linked project information. Digital learning that is not secure may compromise trust, disrupt learning continuity, and endanger sensitive data.

The smart supply chain study adds a governance perspective. Digital transformation is often constrained by high initial investment, weak infrastructure, lack of advanced analytics, insufficient government support, and fragmented strategic vision. Although this study focuses on smart supply chains, the barriers are highly relevant to TVET. Institutions may fail not because they reject innovation, but because they lack the systemic capacity to sustain it. Technology governance in VTE must therefore include infrastructure planning, cybersecurity policy, teacher training, data ethics, platform maintenance, funding, evaluation, and stakeholder coordination. Without governance, digital tools may become disconnected artifacts. With governance, they become part of a coherent learning and career development ecosystem.

3.7 Integrative TVET 5.0 Framework for Career Development

Based on the synthesis, this article proposes an integrative TVET 5.0 framework. The framework connects digital transformation with career development through five mutually reinforcing pillars. It is not intended as a fixed model but as a conceptual guide for curriculum design, institutional strategy, and future research.

Table 2. Integrative TVET 5.0 framework for career development

Framework Pillar	Strategic Meaning for Career Development
Human-centered AI	AI is used to augment human learning, feedback, assessment, simulation, and ethical decision-making rather than replace teachers.
Teachers' digital and AI competence	Educators require integrated technological, pedagogical, and content knowledge to translate AI into meaningful vocational learning.
Industry-responsive curriculum	Learning outcomes, projects, internships, and assessment must reflect smart industry needs, sustainability, and labor market change.
Secure and inclusive digital governance	Institutions need infrastructure, cybersecurity policy, responsible data practices, financing, and inclusive access.
Lifelong career development ecosystem	TVET should provide modular learning, e-portfolios, reskilling, upskilling, and industry-based knowledge networks across the career span.

The framework highlights that no single pillar is sufficient. AI implementation requires competent teachers; teacher competence requires relevant curriculum; digital curriculum requires safe governance; and governance becomes meaningful only when it supports lifelong career development. This systemic view is central to preparing vocational graduates who are employable, adaptable, and resilient in a technology-rich labor market.

4. Conclusions

This integrative review shows that digital transformation in Vocational Technology Education should be interpreted through the lens of career development. The reviewed studies demonstrate that AI, digital competence, e-learning, electronic portfolios, user-generated content, cybersecurity, smart systems, lifelong learning, and Industry 5.0 are interconnected elements of a broader career-oriented TVET ecosystem. The main contribution of this article lies in reframing technology integration as a systemic educational transformation. AI has significant potential to personalize learning, support assessment, and improve instructional efficiency, but its value depends on pedagogical integration, teacher readiness, ethical data use, and institutional support. Similarly, e-

learning resources, e-portfolios, and educational data can enrich vocational learning only when they are aligned with curriculum goals, industry needs, and secure governance structures. The proposed TVET 5.0 framework offers five strategic directions: human-centered AI, teachers' digital and AI competence, industry-responsive curriculum, secure and inclusive technology governance, and lifelong career development ecosystems. These directions suggest that VTE institutions should not merely add digital tools to existing programs. They should redesign learning experiences, professional development, assessment systems, and partnerships so that graduates are prepared for employability, career mobility, and continuous competence renewal in the era of intelligent and sustainable industry.

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