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Design thinking and AI in TVET: driving human-centred digital transformation in vocational education

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Abstract
This systematic literature review explores the convergence of design thinking (DT) and artificial intelligence (AI) as transformative strategies in Technical and Vocational Education and Training (TVET). Amidst accelerating technological shifts, TVET systems face growing pressure to equip learners not only with technical skills but also with creativity, adaptability, and systems thinking. DT and AI, while individually valuable, remain under-integrated in vocational curricula, often limited to isolated pilot initiatives without strategic institutional anchoring. This review synthesizes findings from 12 empirical studies published between 2021 and 2025, analyzing their methodologies, impacts, and thematic contributions. Three overarching themes emerged: (i) design thinking as a driver of pedagogical transformation in vocational settings; (ii) leveraging emerging technologies to personalize and humanize learning in TVET; and (iii) integrating design thinking with institutional strategy for workforce readiness in TVET. While these studies showcase innovative practices, critical gaps persist particularly in long-term scalability, ethical AI integration, and systemic policy frameworks. Notably, few studies operationalize the combined use of DT and AI within holistic institutional strategies. This review argues for a paradigm shift: repositioning TVET as a human-centered engine for digital innovation. It calls for co-created, cross-sector frameworks that embed AI-powered DT models into educational policy and institutional planning. The findings highlight an urgent need for sustainable, evidence-based models to make vocational education responsive, inclusive, and future-ready.

Keywords:
Design thinking; Artificial intelligence; TVET (Technical and Vocational Education and Training); Educational innovation; Digital transformation;

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1. Introduction

In today's digital economy, Technical and Vocational Education and Training (TVET) systems are increasingly recognised for their pivotal role in shaping adaptable, skilled, and innovation-ready

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workforces. However, the accelerating pace of technological change driven by artificial intelligence (AI), robotics, and data systems demands more than conventional training. Educational models must now cultivate broader cognitive and creative capacities among learners, such as design thinking, adaptability, and system-level problem solving (Jusoh et al., 2025).

Design thinking (DT), with its focus on empathetic understanding, user-centred problem framing, and iterative prototyping, offers a promising pedagogical lens through which vocational learners can engage more meaningfully with real-world challenges. Simultaneously, artificial intelligence (AI) technologies are beginning to influence how instruction is delivered, monitored, and personalised. Together, these approaches offer new possibilities for TVET, enabling not only more personalised and responsive learning but also improving learner motivation, creativity, and long-term employability prospects.

Despite these opportunities, empirical studies suggest that the integration of AI and DT into vocational systems remains inconsistent and limited in scale. Initiatives often operate in silos or short-term pilot schemes without clear institutional policies or cross-cutting curriculum reforms to support their sustainability (Hussein et al., 2024). In many contexts, the strategic use of AI tools in TVET is hampered by a lack of infrastructure, professional development, and evidence-informed frameworks (Rajamanickam et al., 2024). Similarly, DT methods, while theoretically well-suited for practical learning, have not yet been mainstreamed across technical curricula or training environments. The absence of shared models that synthesise these two domains complicates this further. While both AI and DT are increasingly seen as central to the future of education, little research has explored how they might work in tandem to support TVET innovation. Moreover, there are clear disparities between regions and institutions regarding access to digital tools, resulting in uneven opportunities for both learners and instructors (Havidotinnisa et al., 2024).

Therefore, this systematic literature review is warranted not simply to collate what has been published but to understand how DT and AI are evolving as complementary strategies for digital and pedagogical transformation in vocational education. By bringing together fragmented insights from academic and applied sources, this review aims to develop a coherent narrative that informs policy, curriculum development and institutional practice. Its primary focus is to identify the ways in which AI and DT have been operationalised in TVET settings, the impact of such practices on learners and educators, and the barriers that persist. In doing so, this study contributes to the global effort of repositioning vocational education as a dynamic, technology-enabled, and human-centred component of lifelong learning systems.

2. Methods

A systematic literature review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. This structured guideline ensures transparency, reproducibility, and methodological rigor during the review process. The review was systematically organised into the following phases: identification, screening, eligibility, and finally, data abstraction and analysis. These phases were grounded in the principles and reporting standards outlined by the PRISMA protocol.

2.1 Identification

The selection of relevant studies for this systematic review followed a structured process comprising three critical stages. The initial stage focused on identifying core keywords and associated terms by consulting authoritative sources such as thesauri, lexicons, encyclopaedias, and prior academic literature. Based on this exploratory analysis, comprehensive search strings

were developed to facilitate targeted searches within the Scopus and Web of Science (WoS) databases, as shown in Table 1. This preliminary search phase yielded 42 academic articles across both databases, forming the initial dataset for further screening and evaluation.

Table 1: Search string

Database	Search String
Scopus	TITLE-ABS-KEY (("design thinking" OR "design-based learning") AND ("vocational education" OR "technical and vocational education" OR "TVET")) AND (LIMIT-TO (PUBYEAR , 2021) OR LIMIT-TO (PUBYEAR , 2022) OR LIMIT-TO (PUBYEAR , 2023) OR LIMIT-TO (PUBYEAR , 2024) OR LIMIT-TO (PUBYEAR , 2025)) AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "cp") OR LIMIT-TO (DOCTYPE , "ch")) AND (LIMIT-TO (PUBSTAGE , "final")) AND (LIMIT-TO (SRCTYPE , "j") OR LIMIT-TO (SRCTYPE , "k") OR LIMIT-TO (SRCTYPE , "b") OR LIMIT-TO (SRCTYPE , "p")) AND (LIMIT-TO (LANGUAGE , "English"))
WoS	(“design thinking" OR "design-based learning") AND ("vocational education" OR "technical and vocational education" OR "TVET") (Topic) and 2021 or 2022 or 2023 or 2024 or 2025 (Publication Years) and Article or Proceeding Paper (Document Types) and English (Languages)

2.2 Screening

During the initial phase of the screening process, seven articles were excluded because of duplication. The subsequent screening stage involved a detailed review of 21 studies based on the inclusion and exclusion criteria established by domain experts. Priority was given to empirical research articles because they offer the most actionable insights for practice. Consequently, non-empirical literature, such as reviews, systematic reviews, meta-analyses, bibliometric studies, and meta-syntheses, was excluded because of its limited alignment with the review’s objectives. Additionally, the selection was confined to English-language publications from the most recent five-year period (2021–2025). Based on these parameters, two articles were excluded from the final dataset.

2.3 Eligibility

In the third stage, referred to as the eligibility assessment, 21 articles were critically examined to determine their alignment with the established inclusion criteria and overarching research objectives. Two studies were excluded because of vague or non-informative titles, abstracts that did not correspond to the aims of the review, or content falling outside the scope of vocational education and innovation. Ultimately, 12 articles were deemed eligible for inclusion, as summarised in Table 2.

Table 2: The selection criterion of searching

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2021-2025 (July, 2025)	< 2021
Literature type	Journal (Article), Conference Proceedings, Book chapters and Book Series,	Review
Publication Stage	Final	In Press

2.4 Data abstraction and analysis

In this study, data from 12 peer-reviewed articles were systematically analysed to explore the integration of design thinking (DT) and artificial intelligence (AI) in Technical and Vocational Education and Training (TVET). Using thematic analysis, three main themes were identified: pedagogical transformation through DT, AI-enabled personalisation and assessment, and the synergy between DT and AI in enhancing vocational learning. The analysis process involved

collaborative coding, iterative theme refinement, and expert validation by specialists in Educational Technology and TVET, ensuring clarity, relevance, and analytical rigor. The entire procedure was conducted in alignment with the PRISMA framework (as shown in Figure 1) to ensure methodological transparency and validity.

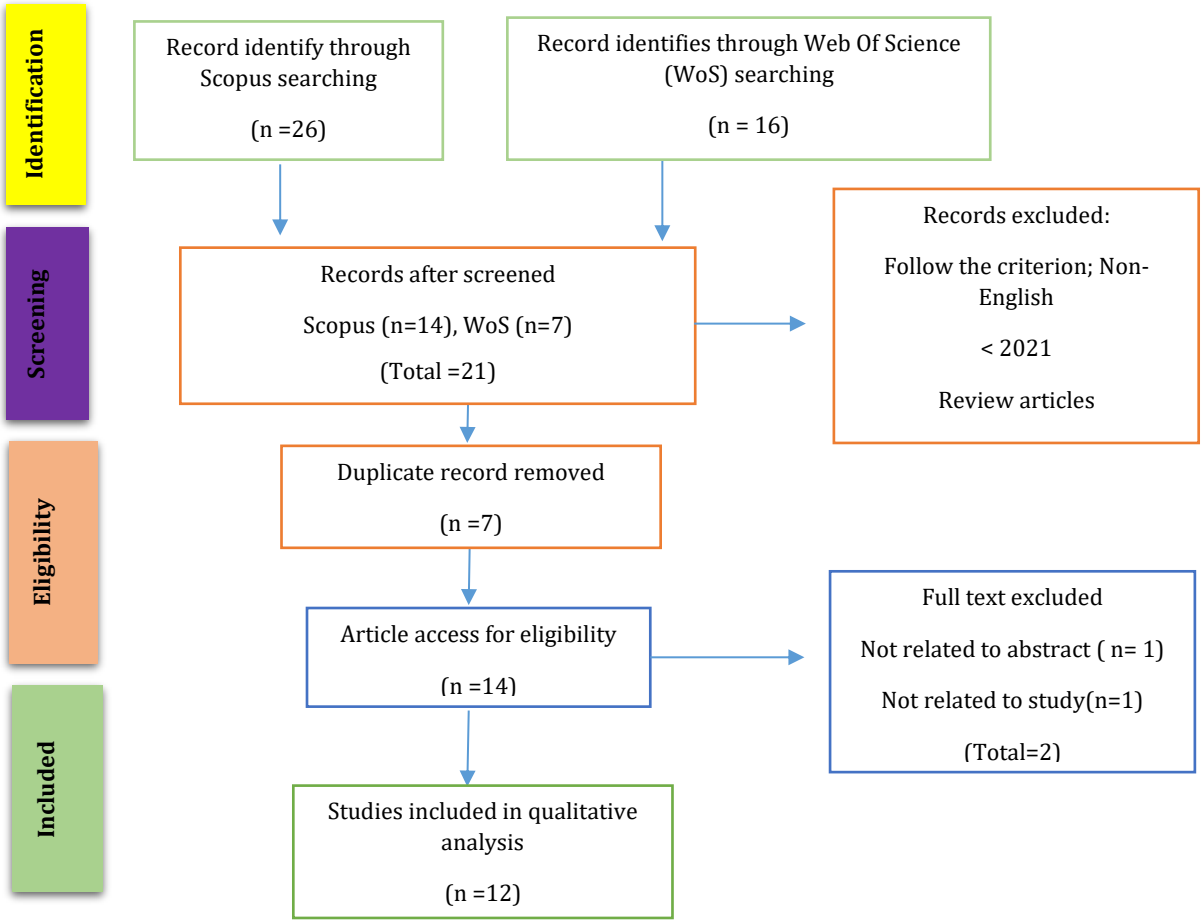

Figure 1: PRISMA framework for included studies

3. Results

This Systematic Literature Review (SLR) synthesises current empirical evidence on the integration of design thinking (DT) and artificial intelligence (AI) within the context of Technical and Vocational Education and Training (TVET). Guided by rigorous inclusion criteria and thematic analysis, three overarching themes were identified across the 12 reviewed studies: (i) design thinking as a driver of pedagogical transformation in vocational settings, (ii) leveraging emerging technologies to personalise and humanise learning in TVET, and (iii) integrating design thinking with institutional strategy for workforce readiness in TVET.

These themes not only reflect the expanding body of scholarship supporting innovation-driven pedagogy in TVET but also reveal ongoing challenges such as infrastructure gaps, educator preparedness, and the lack of standardised frameworks for implementation. Each theme is elaborated below with supporting studies, providing nuanced insights into how DT and AI can empower vocational education while addressing persistent systemic limitations.

3.1 Theme 1: Design Thinking as a driver of pedagogical transformation in vocational settings

This theme encapsulates how Design Thinking (DT) is being adopted to reform vocational education pedagogy through learner-centered approaches, problem-solving models and innovation-focused curricula. All 12 articles reviewed included elements of DT-driven transformation, underscoring its growing relevance in reshaping vocational education is taught and experienced. These studies, as shown in Table 3, reveal that DT encourages engagement, enhances motivation, fosters creativity, and improves the alignment between curriculum and real-world problem-solving.

Table 3: Design thinking as a driver of pedagogical transformation in vocational settings

No.	Author(s)	Focus of study	Key Contribution
1	Merolli et al. (2024)	Digital health module with DT	Developed a curriculum with DT components to train health professionals in digital skills
2	Hoaihongthong et al., (2024)	Secretarial students' digital competence	DT supported digital adaptability, transdisciplinary thinking, and problem-solving
3	Qianqian et al., (2025b)	Career adaptability with DT	DT teaching model improved adaptability in vocational career planning
4	Qianqian et al., (2025a)	DT to enhance classroom atmosphere	Demonstrated that DT fosters a more engaging, positive classroom environment
5	Lin et al., (2024)	DT for learning motivation	Reported significant gains in students' motivation after DT-based intervention
6	Krüger et al., (2024)	DT personality profiling	Created tools to assess DT-inclined personality traits for personalized educational interventions
7	Eamcharoen (2024)	DT via video-based course	Interactive video course based on DT improved knowledge, satisfaction, and innovation skills
8	Adarkwah and Islam (2025)	DT for entrepreneurship training (PWDs)	Used DT empathy-based frameworks to design inclusive learning in immersive/metaverse platforms
9	Liu and Ko (2021)	DT + social media in corporate design education	DT integrated with Facebook/Line enhanced creative outputs in design curriculum
10	Díaz-Lauzurica and Moreno-Salinas (2023)	DT in robotics/programming education	Increased student creativity, self-learning, and motivation through DT-driven projects
11	Wang et al., (2025)	PjBBL-DT blended model	DT fostered creativity and openness in entrepreneurship education
12	Bugliesi and Micelli (2024)	DT for SME innovation training	DT used in executive education to bridge digital skill gaps for vocational graduates

Several studies have confirmed that embedding DT within vocational curricula improves both pedagogical processes and student-level outcomes. For instance, Qianqian et al. (2025b) and Lin et al. (2024) employed DT in career planning modules and observed significant improvements in motivation and adaptability of students. These outcomes were supported by Qianqian et al. (2025a), who found that DT applications enhanced the classroom atmosphere and the quality of student interaction.

Eamcharoen (2024) expanded this line of enquiry by developing an interactive DT-based video course, which yielded measurable improvements in learner engagement, skills acquisition, and overall satisfaction, indicating DT's flexibility across modalities. Meanwhile, Merolli et al. (2024) demonstrated the use of DT in designing digital health curricula that promote innovation and digital literacy among tertiary learners, illustrating its applicability in professional vocational contexts.

Several studies further explored the diagnostic and personalization potential of DT. Krüger et al. (2024) introduced a Design Thinker Personality Profile aligned with the Big Five traits to help tailor instructional approaches to student predispositions. Similarly, Liu and Ko (2021) combined social media and DT in design classes, resulting in a more creative output and improved collaboration. Wang et al. (2025) integrated DT with blended learning to enhance creativity and openness to experience in Chinese vocational students, confirming its psychological and cognitive

impact. Díaz-Lauzurica and Moreno-Salinas (2023) applied DT in robotics education, helping demystify abstract STEM concepts and increasing motivation through project-based exploration.

Finally, studies by Adarkwah and Islam (2025) and Bugliesi and Micelli (2024) emphasized DT's value in inclusive and workforce-aligned innovation training, particularly for marginalized learners and SMEs, highlighting DT as a socially responsive pedagogical model.

3.2 Theme 2: Leveraging emerging technologies to personalize and humanize learning in TVET

This theme emphasises how the use of emerging technologies, particularly those aligned with AI principles and immersive media, enables personalised and inclusive learning in TVET. The reviewed articles in this category showcase a range of innovative tools, such as interactive video-based platforms, metaverse experiences, social media integration, and robotics programming environments. These tools are employed not only for content delivery but also to foster engagement, adaptability, and equity in vocational education.

Eamcharoen (2024) designed an interactive video-based course that incorporated design thinking, which significantly improved vocational students' satisfaction, knowledge, and skill development. Similarly, Adarkwah and Islam (2025) proposed a metaverse-driven framework to empower persons with disabilities (PWDs) and showed how immersive digital platforms can promote inclusive entrepreneurship training. In Taiwan, Liu and Ko (2021) showed that integrating social media into a design thinking-enhanced corporate identity course led to more creative outputs and stronger peer collaboration. Meanwhile, Díaz-Lauzurica and Moreno-Salinas (2023) applied DT in robotics education, which successfully increased student motivation and hands-on programming fluency across vocational and secondary education levels. Together, these studies (as shown in Table 4) provide compelling evidence that emerging technologies grounded in human-centred design can enhance personalisation, support diverse learner needs, and contribute to future-ready TVET systems.

Table 4: Leveraging emerging technologies to personalize and humanize learning in TVET

No.	Author(s)	Focus of Study	Key Contribution
1	Eamcharoen (2024)	Interactive video course using DT to improve student outcomes	Increased satisfaction and knowledge via multimedia instructional design.
2	Adarkwah & Islam (2025)	Metaverse-based inclusive learning for persons with disabilities	Introduced empathy-centered entrepreneurship using immersive learning.
3	Liu & Ko (2021)	Social media-enhanced DT pedagogy in vocational design courses	Boosted creativity and design quality through real-time digital collaboration.
4	Díaz-Lauzurica & Moreno (2023)	Design Thinking in robotics/programming for motivation and skills	Raised engagement and adaptive learning across various education levels.

3.3 Theme 3: Integrating design thinking with institutional strategy for workforce readiness in TVET

This theme explores how design thinking (DT), when strategically embedded at the institutional level, can cultivate workforce-relevant competencies such as creativity, adaptability, and innovation in vocational learners. Unlike isolated pedagogical interventions, these studies emphasize system-wide approaches, where DT is positioned as a foundational philosophy that shapes institutional training programs, entrepreneurial initiatives, and industry collaborations.

Merolli et al. (2024) developed a digital transformation curriculum for professional health education, embedding DT principles to prepare students for the evolving demands of healthcare systems. Their initiative reflected institutional responsiveness to digitalization by aligning

learning outcomes with innovation competencies. Similarly, Bugliesi and Micelli (2024) showcased a collaborative initiative between Italian TVET institutions and SMEs, where DT was employed to bridge skills gaps in digital innovation. This project highlights how DT can be scaled to address systemic labor-market challenges.

Qianqian et al. (2025a) and Qianqian et al. (2025b) demonstrated how DT-enhanced teaching strategies foster positive shifts in the learning atmosphere and career adaptability, both of which are critical for cultivating future-ready graduates. These outcomes are not merely classroom-level improvements but signal the institutional potential for embedding DT into policy and planning. Furthermore, Wang et al. (2025) integrated DT into a blended entrepreneurship education model, showing how openness to experience and creativity can be systematically developed through longitudinal pedagogical innovation. Collectively, the studies shown in Table 5 illustrate that DT is more than a teaching method; it is a strategic lever for institutional transformation, aligning TVET goals with 21st-century workforce needs.

Table 5: Integrating design thinking with institutional strategy for workforce readiness in TVET

No.	Author(s)	Focus of Study	Key Contribution
1	Merolli et al. (2024)	Digital health curriculum integrating DT	Demonstrated institutional curriculum reform grounded in innovation needs.
2	Bugliesi & Micelli (2024)	SME upskilling via DT collaboration with TVET institutions	Addressed industry-academic alignment through workforce digitalization.
3	Qianqian et al. (2025a)	DT to improve learning atmosphere in vocational colleges	Enhanced classroom culture with systemic implications for teaching quality.
4	Qianqian et al. (2025b)	DT-based career adaptability training in TVET	Boosted student preparedness for dynamic labor markets.
5	Wang et al. (2025)	Blended learning with DT to foster creativity and openness	Validated a scalable model to cultivate innovation competencies institutionally.

4. Discussion and conclusion

The first theme highlights the integration of design thinking (DT) and artificial intelligence (AI) to cultivate core competencies in vocational learners, such as creativity, motivation, and adaptability. These studies offer substantial evidence that DT-enhanced learning interventions positively influence learners' psychological and cognitive dimensions, particularly in the context of career planning, classroom dynamics, and student engagement. However, while many of these interventions report statistically significant outcomes, they are often localised to small-scale implementations or single-institution contexts and lack longitudinal or comparative validation. The novelty lies in showcasing how DT and AI can move beyond toolkits into mechanisms that foster learner transformation. However, a major gap persists in scaling these practices and assessing their long-term employability impacts in TVET environments.

The second theme is emerging technologies as enablers of personalised and humanised vocational learning. Studies that incorporate the metaverse, interactive video, and robotics underscore the potential of immersive media and AI-powered systems to promote inclusion, digital creativity, and adaptive learning. These approaches not only personalise content but also humanise learning experiences for underserved groups, such as persons with disabilities or under-motivated students. Despite their promise, these interventions are often technologically siloed, with limited articulation of how AI systems interface with pedagogical design and broader institutional goals. A critical novelty of this study is the conceptual blending of empathy-driven DT and data-driven AI to foster learner agency. However, the lack of interoperable frameworks or ethical guardrails for technology integration signals an urgent need for policy-aligned research.

The final theme positions DT as a strategic institutional philosophy rather than a classroom technique, thereby pushing the boundaries of traditional pedagogy. Through cross-sector collaborations (e.g., with SMEs), curriculum reforms, and interdisciplinary models, DT is framed as a vehicle for workforce readiness and innovation alignment in TVET. These studies provide preliminary evidence that DT can be institutionalised to bridge skills gaps and support digital transitions. However, the novelty of this insight is tempered by the absence of system-wide implementation roadmaps, evaluation metrics, and governance models. Most studies remain exploratory, with little attention paid to change management, organizational learning, or policy infrastructure. This highlights a pressing research gap: the need for holistic models that embed DT and AI within institutional strategies, pedagogy, and sustainable industry partnerships.

This systematic review reveals a growing yet fragmented body of scholarship examining the convergence of DT and AI in TVET. Across three thematic domains–(i) learner-centred enhancement, (ii) immersive technological integration, and (iii) institutional strategy for workforce alignment–evidence suggests that DT and AI can significantly enrich vocational pedagogy, foster digital adaptability, and promote inclusion. Notably, these innovations align with the 21st-century demand for agile, creative, and self-directed learners.

However, the review also exposes critical deficiencies in its scope and depth. Most studies are exploratory, context-specific, or lack theoretical and methodological coherence. Longitudinal analyses are rare, and the absence of unified implementation frameworks constrains scalability and policy integration in this field. Furthermore, few studies have operationalised the intersection of DT and AI through robust institutional models or assessed the ethical and infrastructural readiness of TVET systems.

To advance this field, future research must move beyond pilot interventions and toward a systemic design. This includes co-developing AI-powered DT frameworks with stakeholders, embedding them in policy blueprints, and validating their efficacy across diverse vocational contexts. Scholars, technologists, and policymakers are urged to collaboratively construct evidence-based pathways that reimagine TVET not only as a skills provider but also as a transformative force in the digital economy. The time to reengineer vocational education through human-centred innovation is now.

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Authors' contribution: Mohd Yahya Fadzli Jusoh conceptualised the research idea, coordinated the writing process, and compiled the final manuscript. Azmir Ahmad provided input on the theoretical framework and assisted in reviewing AI in TVET practices. Poovaneswari Elumalai contributed to the data synthesis and design thinking integration. Shahrul Amri Mohamad reviewed the manuscript and provided constructive feedback for its refinement.

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