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A Decade of Artificial Intelligence in Technical and Vocational Education and Training: A Bibliometric Analysis of Trends and Research Trajectories

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Abstract: The integration of Artificial Intelligence (AI) in Technical and Vocational Education and Training (TVET) has gained significant traction over the past decade. AI-driven technologies are transforming skills acquisition, workforce development, and educational methodologies. Despite this increasing interest, there remains a limited comprehensive bibliometric analysis mapping the research landscape. This study aims to analyze trends, scholarly contributions, and emerging themes in AI applications within TVET, providing a structured understanding of its evolution and identifying research gaps. A bibliometric approach was utilized to analyze AI-related research in TVET from 2015 to 2024. Data was sourced from Dimensions.ai, ensuring coverage of peer-reviewed journal articles and conference proceedings. The study employed the bibliometric tool VOSviewer for citation network analysis, keyword co-occurrence mapping, and authorship collaboration patterns. Descriptive statistics and trend analysis were applied to assess publication growth, influential authors, institutions, and countries. The findings indicate a steady increase in AI-TVET research, with a notable surge post-2019 due to advancements in adaptive learning systems, machine learning applications, and intelligent tutoring systems. Keyword analysis revealed dominant themes, including personalized learning, automation in vocational training, and AI-driven competency assessments. However, gaps remain in research addressing AI ethics, accessibility, and effectiveness in skill-based education. This study highlights the transformative role of AI in TVET, emphasizing the need for interdisciplinary collaboration and policy alignment. Future research should explore AI's long-term impact on vocational skills and employability. The insights from this bibliometric analysis serve as a foundation for guiding policymakers, educators, and researchers toward more strategic AI integration in TVET.

Keywords: artificial intelligence; AI; bibliometric analysis; co-citations; TVET; visualizations; VOSviewer.
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Introduction

The convergence of Artificial Intelligence (AI) and Technical and Vocational Education and Training (TVET) represents a dynamic and evolving area of research, where technological innovations are driving transformative changes in workforce development. AI, with its potential to revolutionize education systems, is increasingly integrated into TVET to enhance personalized learning, automate skill assessment, and simulate real-world work environments (Panigrahi et al., 2021). However, understanding the research trends, emerging themes, and influential works in this interdisciplinary domain requires systematic inquiry. A bibliometric analysis offers an evidence-based approach to comprehensively map the evolution of research, identify scholarly contributions, and uncover gaps, making it an essential methodology for such an investigation.

Bibliometric studies are an established methodology in scholarly research, offering quantitative tools to analyze publication patterns, citation structures, and intellectual linkages across disciplines (van Eck & Waltman, 2010). These methods enable researchers to identify influential authors, journals, institutions, and thematic clusters within a body of literature. First introduced by Pritchard (1969), bibliometric approaches are widely applied in various fields to track research trends, evaluate academic performance, and support strategic policymaking in education and beyond. The

advent of advanced tools like VOSviewer and CiteSpace has further enhanced the ability to visualize relationships between authors, keywords, and citations, providing actionable insights for academia and industry.

Artificial Intelligence has emerged as a transformative technology across disciplines, including education. AI applications in education range from adaptive learning systems to intelligent tutoring and natural language processing for automated feedback (Wayne et al., 2019). In TVET, AI holds significant promise for creating scalable, cost-effective solutions for training a future-ready workforce. For example, AI-powered simulations can mimic real-world scenarios for skill training, while machine learning models can identify and address learner-specific needs. As a critical enabler of Industry 4.0, AI's integration into TVET is not just a pedagogical advancement but a socio-economic imperative to bridge the skills gap and ensure global competitiveness (UNESCO, 2019).

TVET plays a pivotal role in equipping individuals with the practical skills and competencies required in rapidly evolving industries. Unlike traditional academic pathways, TVET emphasizes hands-on training, employability, and responsiveness to market demands. However, with the increasing automation of routine tasks, the need for advanced technical and cognitive skills is accelerating, placing AI-driven innovations at the forefront of TVET reforms. The adoption of AI in TVET also aligns with global sustainable development goals (SDGs), particularly SDG 4, which emphasizes inclusive and equitable quality education and lifelong learning opportunities (UNESCO, 2016).

Bibliometric analysis offers a systematic approach to understanding the research landscape, making it particularly well-suited for studying the intersection of Artificial Intelligence (AI) and Technical and Vocational Education and Training (TVET). For the period between 2015 and 2024, bibliometric analysis is justified by the rapid growth of AI applications in education and the increasing global recognition of TVET as a critical enabler of workforce readiness. By mapping the research trends and intellectual contributions in this domain, bibliometric analysis provides valuable insights into how AI is reshaping vocational training and education systems to address evolving skill demands. This approach not only highlights the maturity of the field but also identifies emerging topics and underexplored areas, offering a comprehensive perspective on the development of AI-driven innovations in TVET.

One of the key contributions of bibliometric analysis is its ability to map research trends. This study systematically tracks the evolution of AI in TVET research over a decade, enabling the identification of recurring themes, significant milestones, and thematic shifts. Such insights are instrumental in uncovering knowledge gaps and guiding future research directions. Furthermore, by identifying highly cited works, prominent authors, and influential institutions, bibliometric analysis underscores the foundational contributions that have shaped the discourse on AI in TVET. This visibility is essential for understanding the intellectual structure of the field and for fostering collaboration between scholars and institutions.

In addition to its academic contributions, bibliometric analysis also has significant practical implications for policy and practice. Policymakers, educators, and industry stakeholders can benefit from the data-driven insights provided

by this study, using them to design targeted interventions and investments in AI-integrated TVET programs. For example, understanding the areas where AI has been most impactful or where it remains underutilized can help prioritize resource allocation and policy reforms. In this way, bibliometric analysis serves as both a reflective and strategic tool, bridging the gap between academic research and real-world applications. By leveraging bibliometric methodologies, this study provides an empirical foundation for understanding the dynamics of AI in TVET research. The findings contribute to advancing knowledge, shaping research agendas, and supporting evidence-based policymaking in a field that is critical to addressing the workforce challenges of the 21st century.

Theoretically, this bibliometric study contributes to the understanding of how emerging technologies like AI are integrated into education systems, particularly in skill-based learning environments. It draws on sociotechnical systems theory, which examines the interplay between technology, people, and processes, to highlight the transformative potential of AI in TVET. Methodologically, this study leverages advanced bibliometric tools like VOSviewer to analyze citation networks, co-authorship patterns, and thematic clusters. These visualizations provide a granular understanding of the intellectual structure and research priorities in AI in TVET, enabling the identification of trends, gaps, and opportunities.

In conclusion, this bibliometric investigation of AI in TVET research from 2015 to 2024 offers a timely and comprehensive perspective on the field's development. By synthesizing knowledge across disciplines and providing actionable insights, it aims to advance academic research and inform evidence-based policy and practice in integrating AI into TVET systems. This study was guided by the following research objectives. To:

i. Identify major trends in the research of AI in TVET
ii. Highlight key contributors, institutions and countries leading the research of AI in TVET
iii. Map knowledge gaps and suggest future directions of research in AI in TVET
iv. Analyse emerging research themes on AI in TVET research.

Literature Review

Artificial Intelligence (AI) has emerged as a transformative force in education, facilitating applications such as personalized learning systems, intelligent tutoring, automated assessments, and simulation-based training. Recently, AI has gained traction in educational environments to address challenges such as student engagement and the scalable delivery of education (Panigrahi et al., 2021; Wayne et al., 2019). AI-driven tools enhance learner-centered approaches and leverage predictive analytics to refine teaching and learning strategies. However, despite advancements in general education, the integration of AI into Technical and Vocational Education and Training (TVET) remains underexplored, warranting a focused examination of its role within this sector.

TVET is crucial for equipping individuals to meet the evolving demands of the labor market. In contrast to traditional education, TVET prioritizes skill acquisition, hands-on training, and employability (UNESCO, 2019). The Fourth Industrial Revolution, characterized by advancements in AI, robotics, and automation, necessitates that TVET

institutions adapt their curricula to bridge skill gaps and prepare students for technology-driven industries (Singh et al., 2021). Research indicates AI's potential to enhance training quality and employability while also identifying barriers such as insufficient institutional readiness, inadequate digital infrastructure, and a lack of teacher competencies in AI-based pedagogy (Ali et al., 2024; Shiohira, 2021).

Integrating AI into TVET presents opportunities to address challenges such as limited resource access and the need for personalized instruction. AI-powered tools, including virtual reality simulations and adaptive learning platforms, create realistic environments for safe skill practice (Jiang et al., 2023). Furthermore, AI applications in competency-based assessments enable accurate evaluations of learners' skills and facilitate personalized feedback (Sheila et al., 2021). Despite these advancements, empirical studies on AI's effectiveness in TVET are limited, often comprising fragmented case studies that fail to provide a comprehensive overview of AI's overall impact on TVET systems.
Challenges associated with the adoption of AI in TVET include high implementation costs, ethical concerns regarding data privacy, and the necessity for specialized teacher training (Teo et al., 2016). Additionally, the lack of standardized frameworks for AI integration in TVET hinders scalability and comparability across institutions and regions. These challenges underscore the need for more holistic and data-driven studies to inform AI adoption in TVET settings.

Artificial Intelligence (AI) is revolutionizing education through the development of personalized learning systems, intelligent tutoring, automated assessments, and simulation-based training. Recently, AI has garnered attention in educational environments to tackle challenges such as student engagement and scalable educational delivery (Holmes et al., 2019; Panigrahi et al., 2021). AI-driven tools facilitate learner-centered methodologies and utilize predictive analytics to refine teaching and learning strategies. However, while advancements in general education are notable, the incorporation of AI into Technical and Vocational Education and Training (TVET) remains largely unexplored, warranting targeted investigation.

TVET plays a vital role in equipping individuals to meet labor market demands. Distinct from traditional education, TVET prioritizes skill acquisition, practical training, and employability (UNESCO, 2019). The Fourth Industrial Revolution, marked by AI, robotics, and automation, necessitates that TVET institutions revise curricula to bridge skill gaps and prepare students for technology-driven industries (Singh et al., 2020). Research suggests that AI can enhance training quality and employability; however, obstacles persist, including insufficient institutional readiness, inadequate digital infrastructure, and a lack of teacher competencies in AI-based pedagogy (Chinien & Boutin, 2020).

The integration of AI into TVET offers opportunities to address challenges such as limited access to resources and the increasing demand for personalized instruction. AI-powered tools, including virtual reality simulations and adaptive learning platforms, create immersive environments for skill development (Jiang et al., 2023). Furthermore, AI applications in competency-based assessments allow for precise evaluations of learners' skills and provide tailored feedback (Sheila et al., 2021). Despite these advancements, empirical studies evaluating AI's effectiveness in TVET

are limited and often consist of fragmented case studies that fail to deliver a comprehensive understanding of AI's impact on TVET systems.

Challenges associated with adopting AI in TVET include high implementation costs, ethical concerns regarding data privacy, and the necessity for specialized teacher training (Teo et al., 2016). The absence of standardized frameworks for AI integration in TVET hampers scalability and comparability across institutions and regions. These challenges highlight the urgent need for comprehensive, data-driven research to inform AI adoption in TVET contexts.

Artificial Intelligence (AI) encompasses computational systems that perform tasks traditionally associated with human intelligence, including pattern recognition, predictive analytics, adaptive decision-making, and automated feedback (Holmes et al., 2019). In the field of education, AI applications include intelligent tutoring systems, adaptive learning platforms, automated assessment tools, learning analytics, and immersive simulation environments (Panigrahi et al., 2021).

Within Technical and Vocational Education and Training (TVET), AI serves a dual function. It enhances instructional delivery through simulations, competency-based analytics, and personalized feedback (Jiang et al., 2023) and contributes to the evolving skillset required in Industry 4.0 labor markets (Singh et al., 2020). TVET systems are strategically positioned at the intersection of skills formation and workforce responsiveness (UNESCO, 2019), rendering AI integration a structural transformation in vocational training aligned with automation, robotics, and digitalization.

Bibliometric analysis systematically evaluates the structure and evolution of scientific knowledge through publication metadata, citation patterns, keyword co-occurrence, and collaboration networks (Donthu et al., 2021). Unlike traditional narrative reviews, bibliometric approaches provide a systematic mapping of research landscapes, enabling scholars to identify growth trajectories, dominant themes, influential authors, and the geographic distribution of knowledge production.

Bibliometric techniques are particularly beneficial in emerging interdisciplinary domains where conceptual boundaries are still developing (Aria & Cuccurullo, 2017). By visualizing thematic clusters and citation networks, bibliometric analysis uncovers intellectual structures and research gaps that may not be apparent through descriptive methods. In rapidly evolving fields such as AI in education, bibliometric studies yield insights into the progression of research agendas over time and pinpoint areas of concentrated or insufficient scholarly attention.

Numerous bibliometric investigations have explored AI in education more broadly. For instance, Zawacki-Richter et al. (2019) conducted a systematic review mapping AI application in higher education, noting themes such as adaptive learning and automated assessment while highlighting a limited engagement with ethical considerations. Chen et al. (2020) analyzed global research trends in AI-supported learning analytics, revealing rapid publication growth but an

uneven geographic distribution. These studies provide macro-level insights but primarily concentrate on higher education and general educational technology, with minimal focus on vocational systems.

Bibliometric analyses in educational technology have traced the evolution of digital learning research. For example, Bond et al. (2021) mapped trends in digital transformation research, underscoring the accelerated adoption of technology during the COVID-19 pandemic. Such studies illuminate shifts in research priorities but often neglect sector-specific domains like TVET.

Bibliometric studies in TVET have examined themes such as employability, skills development, and workforce alignment (Li & Pilz, 2021). However, these investigations rarely focus specifically on AI integration. When AI is mentioned, it is typically discussed within the broader context of Industry 4.0 or digitalization, lacking systematic thematic mapping.

While bibliometric research has explored AI in education and TVET scholarship independently, there is a scarcity of intersectional analysis explicitly concentrating on AI within TVET contexts. Although AI research in education has been extensively mapped at a general level, TVET-specific AI scholarship remains under-explored as a distinct domain. Existing studies often evaluate isolated technological applications rather than examining the structural evolution of AI-TVET knowledge production. There appears to be no comprehensive bibliometric investigation that systematically maps publication growth, collaboration networks, geographic distribution, and thematic evolution of AI in TVET over an extended decade-long period.

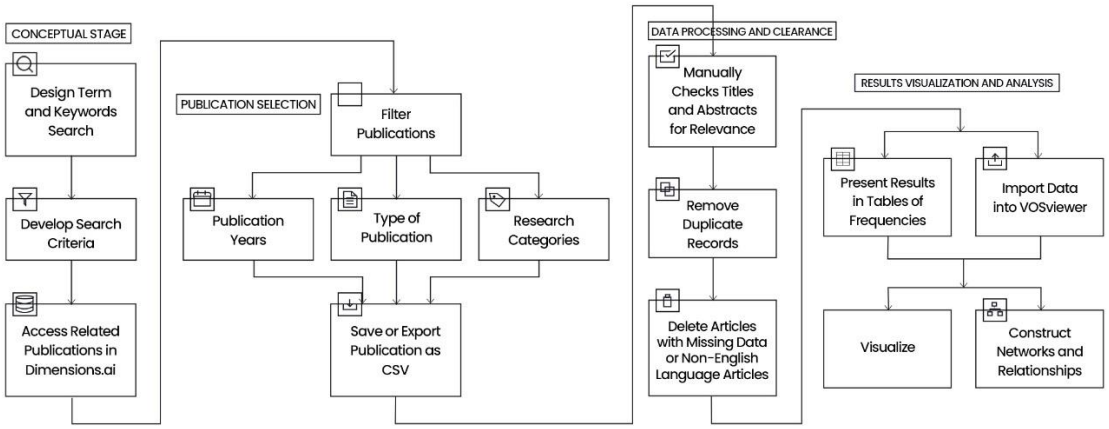
This lack of structured knowledge mapping restricts theoretical consolidation and policy guidance. Without a clear understanding of how AI-TVET research has developed—who produces it, where it is concentrated, and which themes dominate—it becomes challenging to identify neglected areas or inform strategic development. This study aims to address this gap by conducting a decade-long bibliometric investigation of AI-TVET scholarship, providing a systematic analysis of trends, collaboration patterns, and thematic structures. It offers foundational insights into the intellectual architecture of this emerging interdisciplinary field and informs future research and policy directions.

Methodology

The methodological framework for this study employed a systematic bibliometric approach to investigate scholarly trends at the intersection of Artificial Intelligence (AI) and Technical and Vocational Education and Training (TVET). Bibliometric analysis quantitatively assesses academic literature through publication trends, citation analysis, keyword mapping, and collaboration networks (Donthu et al., 2021). This study adheres to a structured model comprising four main phases: Conceptual Stage, Publication Selection, Data Processing and Cleaning, and Results Visualization and Analysis (see Figure 1).

Figure 1

The Bibliometric Approach Framework for the study



Conceptual Stage

The Conceptual Stage laid the foundation for the bibliometric investigation. It commenced with the formulation of search terms and keyword combinations to accurately capture the scope of AI applications within TVET contexts. This step was critical, as the specificity of the search strategy significantly influences the quality of the results (Zupic & Cater, 2015). Through literature reviews and consultations with experts, the researcher established a comprehensive list of search criteria that included variations and synonyms of relevant keywords. To ensure relevant search results, keywords and Boolean operators were employed: "Artificial Intelligence AND TVET," "AI AND TVET," "Artificial Intelligence AND Technical and Vocational Training," and "GenAI." These terms encompass a wide range of literature, incorporating both formal terminology and commonly used abbreviations. The inclusion of "GenAI" addresses discussions surrounding Generative AI, which is increasingly utilized in TVET contexts.

The search concentrated on journal articles and conference proceedings published in English during this decade. After removing duplicates and screening for relevance through title and abstract reviews, the final dataset comprised 44 publications. Although this dataset may appear limited in comparison to the broader AI literature, it signifies the emerging and specialized nature of AI-TVET research. Bibliometric studies in nascent fields typically yield concentrated datasets that provide valuable insights into foundational trends, thematic development, and collaborative networks. Therefore, this dataset is well-suited for mapping the structural development of this evolving interdisciplinary field.

Relevant publications were sourced from scholarly databases, primarily from **Dimensions.ai**, an extensive research database encompassing scholarly articles, preprints, datasets, grants, and patents (Hook et al., 2018, 2021). Utilizing Dimensions.ai ensured broad coverage of academic output, thereby enhancing the reliability of bibliometric metrics.

Publication Selection

The Publication Selection phase refined the initial data pool by applying filters to ensure relevance. Three key criteria guided the filtering process: Publication Years, Type of Publication, and Research Categories. The publication timeframe was established from 2015 to 2024 to capture developments during a period marked by rapid advancements in AI technologies and their integration into educational models, particularly in skills-based learning environments. Filtering by publication year enabled researchers to examine temporal trends, such as the increasing integration of AI in vocational settings. The type of publication filter differentiated between peer-reviewed articles, conference proceedings, and other formats, ensuring consistency in data quality. To emphasize scholarly contributions, publication types were restricted to articles, conference proceedings, and book chapters. These formats represent peer-reviewed, citable academic outputs that significantly contribute to ongoing research discussions (Bornmann & Mutz, 2015; Zahra et al., 2021). Other formats, such as preprints, editorials, and grey literature, were excluded to maintain data quality and reliability for citation-based and content-based analyses. The search yielded 47 publications, which formed the dataset for this study.

Table 1

Publication search criteria for data retrieval

Criteria	Description
Source database	Dimensions.ai
Years	2015 - 2024
Search terms	Artificial Intelligence AND TVET OR "AI AND TVET" OR "Artificial Intelligence" AND "Technical and Vocational Training" OR "GenAI"
Inclusion Criteria	English AND Article OR Chapter OR Proceedings
Exclusion Criteria	Preprint, monograph, edited book and seminar
Sourced date	9th March, 2025

Categorizing publications by relevant disciplines aided in the elimination of irrelevant documents that, despite containing matching keywords, fell outside the study's thematic boundaries. Once filtered, the publications were saved and exported in CSV format, compatible with bibliometric tools such as VOSviewer, Excel, and R (Aria & Cuccurullo, 2017). This structured export facilitated a seamless transition into the subsequent stages of data processing and analysis.

Data Processing and Clearance

Following the data collection phase, a comprehensive data cleaning and preparation process was undertaken to ensure the reliability and validity of the bibliometric analysis. The initial raw dataset obtained from the Dimensions.ai database consisted of 47 publications from 2015 to 2024 and was saved as a CSV (MS-DOS) file. To refine this dataset for focused analysis, a manual screening process was implemented in accordance with established bibliometric methodologies (Ebrahim, 2017; Zupic & Cater, 2015).

To maintain consistency and clarity in interpreting titles and abstracts—critical for keyword co-occurrence and thematic mapping—publications with titles in languages other than English were excluded. Additionally, studies that, despite having overlapping keywords, were unrelated to Artificial Intelligence (AI) and Technical and Vocational Education and Training (TVET) were manually removed. This step was essential for preserving topical accuracy and minimizing noise in the analysis (Donthu et al., 2021; Linnenluecke et al., 2020). Furthermore, entries with incomplete bibliometric information, such as missing authorship, publication year, or citation metrics, were excluded, as such incomplete records could distort analytical outputs, particularly in co-authorship and citation analyses (Ebrahim, 2017; Hook et al., 2021).

Upon completion of the data cleaning process, the refined dataset underwent quantitative bibliometric analysis. The data was organized and tabulated according to publication frequency and citation counts, which are key indicators of scholarly influence and productivity (van Eck & Waltman, 2010). These frequency tables facilitated the identification of the most cited papers, prolific authors, dominant journals, and leading institutions contributing to the AI–TVET research landscape.

Results Visualization and Analysis

To enable network visualization, the cleaned data was imported into VOSviewer, a widely recognized tool for constructing and visualizing bibliometric networks (van Eck & Waltman, 2010). VOSviewer allowed for the creation of various visual maps, including co-authorship networks, keyword co-occurrence maps, and citation networks, thereby providing a structural overview of collaboration patterns, thematic clusters, and intellectual connections within the field (Baako & Abroampa, 2023). The results were further presented using frequency tables, which detailed metrics such as the number of publications per year, the most prolific authors, the top contributing journals, and the leading countries or institutions in the domain of AI in TVET. This descriptive analysis provided a macro-level overview of publication trends. Utilizing VOSviewer, the study visualizes author collaboration networks, institutional linkages, and thematic clusters of keywords. These visualizations facilitate the identification of emerging research themes, key contributors in the field, and potential knowledge gaps.

This study employed a standard bibliometric framework that ensured rigor and transparency in identifying trends, gaps, and emerging areas at the intersection of AI in TVET research. By utilizing Dimensions.ai for data access, exporting in CSV format, and analyzing networks with VOSviewer, the study adhered to best practices in bibliometric research, thereby ensuring methodological rigor (Donthu et al., 2021; Koseoglu, 2016). This systematic approach laid the groundwork for informed decision-making, strategic research planning, and the identification of underexplored areas within the field.

This study is constrained by its reliance on a single bibliographic database and its focus on English-language publications, which may result in the exclusion of important regional scholarship. Although bibliometric analysis

provides insights into publication trends, it does not assess the quality or impact of individual studies. Future research could improve the understanding of methodological rigor and policy influence in AI-TVET research by incorporating multi-database comparisons and content analysis.

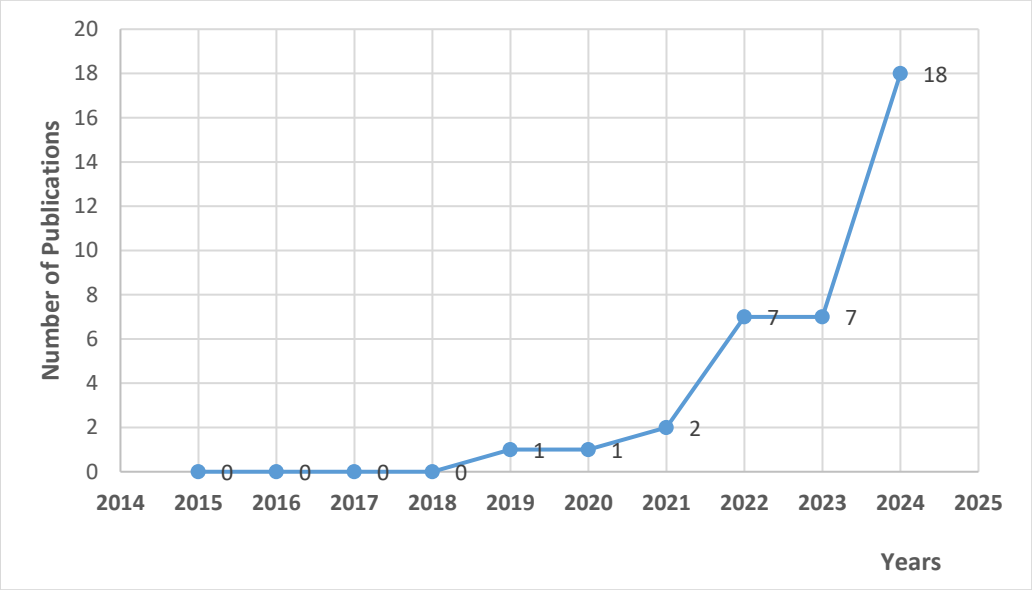
Results

Number of Publications on AI in TVET per year for 2015 – 2024

The study aimed to map research trends in artificial intelligence (AI) in technical and vocational education and training (TVET) from 2015 to 2024. Its objectives were to identify patterns of scholarly interest, evaluate the growth and distribution of publications, and reveal emerging themes and gaps to inform future research and policy development. The findings related to the number of publications during this period are presented in Figure 2.

Figure 2

Number of publications on research related to AI in TVET



The graph (Figure 2) illustrating publications on Artificial Intelligence (AI) in Technical and Vocational Education and Training (TVET) from 2015 to 2024 highlights an emerging research area. From 2015 to 2018, there were no publications, indicating minimal scholarly interest in the intersection of AI in TVET. This dormant phase was succeeded by a modest increase in 2019 and 2020, with one publication recorded in each year.

Beginning in 2021, the field experienced significant growth. Publications rose to two in 2021 and surged to seven in both 2022 and 2023. The most notable increase occurred in 2024, where publications sharply escalated to eighteen, more than doubling the previous peak. This surge is likely associated with the global acceleration of AI research and its applications in education, propelled by advancements in technologies such as ChatGPT and adaptive learning tools.

The trend indicates that the intersection of AI and TVET is a rapidly expanding area of study. The peak in 2024 may represent a breakthrough year, expecting a sustained research momentum in 2025 through continuous funding and collaboration.

Publication Prominence on AI in TVET based on citations

This section presents significant publications on AI in TVET using the citation numbers for scholarly contributions. It assesses the impact of these publications within the academic community and highlights influential research that shapes the field. By evaluating citation trends, this analysis offers insights into the most referenced works, the evolution of AI applications in TVET, and foundational studies that guide further research and policy development in this area.

Of the 38 documents reviewed, seven contained a minimum of three citations. Data derived from VOSviewer identifies the leading publications in Artificial Intelligence (AI) and Technical and Vocational Education and Training (TVET) from 2019 to 2024, ranked according to citation count. This analysis offers valuable insights into the scholarly impact and visibility of research within this field.

Table 2

Top 7 Publications on AI in TVET with at least 3 citations for the period of 2015 – 2024 (ranked according to number of citations)

SN	Publication	Citations
1	Bin Amdam (2024)	12
2	Faisal Rashid (2024)	10
3	Guo (2019)	7
4	Lim (2024)	5
5	Sun (2023)	4
6	Emersic (2024)	3
7	Diachuk (2024)	3

The most cited publication is *Bin Amdan (2024)* with 12 citations, indicating a significant contribution to the field in a relatively short time. Following closely is *Faisal Rashid (2024)* with 10 citations and *Guo (2019)* with 7. These three publications stand out as the most influential, suggesting that their content likely addresses key themes or offers groundbreaking findings relevant to the intersection of AI and TVET. Notably, *Lim (2024)* and *Sun (2023)* also have

moderate citation counts (5 and 4 respectively), reinforcing the trend of increasing impactful research in the most recent years.

Other publications such as Emersic (2024) and Diachuk (2024) have received 3 citations each. While these numbers are relatively low, they still indicate academic engagement and potential for future influence as the field matures. The overall citation pattern reveals a surge in relevant publications from 2022 to 2024, which mirrors the growth trend seen in the earlier bibliometric analysis of publication frequency. Interestingly, older publications like *Guo (2019)* continue to receive citations, highlighting their foundational value in setting the stage for newer studies.

These findings have several implications. First, the prominence of recent works reflects the dynamic and rapidly evolving nature of AI in the context of vocational education, with researchers increasingly contributing to the discourse (Skerritt, 2023). Second, the citation disparity points to a concentration of influence around a few key papers, possibly due to the novelty, relevance, or methodological strength of those studies. The data suggests that impactful research in this space is relatively recent, implying a still-maturing field with opportunities for further exploration and citation growth (Baharin et al., 2025). This citation-based bibliometric analysis reinforces the need for continued research investment in AI and TVET, especially in producing high-quality, widely applicable studies that can shape policy, practice, and future academic inquiry.

Author Prominence on Citations

The study also extracted and analyzed the data on the most prominent authors based on their citations to identify key contributors, assess their influence in the field, and understand the scholarly impact of their work on AI and TVET. This step is significant as it helps in recognizing authoritative voices in the domain, tracking research trends, and determining the concentration of expertise in specific regions or institutions. By analyzing citation patterns, the study provides insights into knowledge dissemination, collaboration networks, and potential research gaps that can inform future studies.

Bibliometric studies emphasize the importance of citation analysis in evaluating research impact, as citations indicate how widely an author's work is acknowledged and integrated into further academic discussions (Hook et al., 2021). Moreover, identifying leading scholars facilitates academic networking, encourages interdisciplinary collaborations, and supports the development of targeted research policies (Suharso et al., 2021) to enhance knowledge advancement in AI applications within TVET.

Of the 111 authors, only 10 met the threshold of authors with at least 5 citations. Table 3 presents data on the top 10 authors with most citations and at least, a publication.

Table 3

Top 10 authors with most citations and at least a publication on AI and TVET within 2015 to 2024

SN	Author	Publications	Citations
1	bin Amdan, Mohammad Aniq	1	12
2	bin Jasman, Mohd Norhazli	1	12
3	bin Kasdiah, Mohd Aidil Hazidi	1	12
4	Janius, Naldo	1	12
5	Faisal Rashid, Sheikh	1	10
6	Duong-Trung, Nghia	1	10
7	Pinkwart, Niels	1	10
8	Guo, Xiaohui	1	7
9	Lee, Ming Foong	1	5
10	Lim, Soon Chong Johnson	1	5

The data highlights the ten most cited authors in the fields of Artificial Intelligence (AI) and Technical and Vocational Education and Training (TVET) from 2015 to 2024. Leading the ranking are three authors—Mohammad Aniq Bin Amdan, Mohd Norhazli Bin Jasman, and Mohd Aidil Hazidi Bin Kasdiah—who each have 12 citations. Their shared top position suggests a collaborative or thematically aligned research focus that has garnered significant academic interest.

In the subsequent tier are Sheikh Faisal Rashid, Nghia Duong-Trung, and Niels Pinkwart, each with 10 citations, indicating their substantial influence in shaping discussions within AI and TVET. The remaining authors, including Xiaohui Guo, Ming Foong Lee, and Soon Chong Johnson Lim, have citations ranging from 5 to 7, reflecting a meaningful, albeit moderate, academic impact.

The prominence of these authors suggests that AI in TVET research is still emerging, with a few key scholars making notable contributions. The relatively modest citation counts—even for the top-ranked authors—indicate that while the field is growing, it may still be in its early stages of consolidation. The clustered citation patterns suggest that researchers are coalescing around certain influential works or thematic directions, such as AI integration in skills development, smart education tools, or competency-based learning models in vocational contexts. Notably, the diversity of author backgrounds (from Southeast Asia, Europe, and beyond) highlights a global interest in applying AI to vocational education, although regions such as Africa and Latin America appear underrepresented.

The bibliometric analysis indicates that the field of artificial intelligence (AI) and technical and vocational education and training (TVET) is gradually identifying its emerging thought leaders. Authors with the highest citation counts are likely influencing key conversations and foundational ideas within this domain. Their works may establish the groundwork for future theoretical and applied studies, positioning them as essential references for subsequent research.

This presents an opportunity for newer scholars to engage with these foundational works, build upon them, or provide critical perspectives that expand the field's scope and relevance (Zahra et al., 2021).

Despite the presence of these influential authors, the overall citation counts remain relatively modest, indicating that the research field is still developing. This underscores the need for more collaborative research networks to strengthen and unify the discourse surrounding AI applications in vocational education. Encouraging partnerships across institutions, disciplines, and regions can consolidate fragmented efforts and foster innovation.

Sources (journals) and number of citations

The study extracted and analyzed data from prominent journals based on citation counts to identify the leading publication outlets contributing to the discourse on AI in Technical and Vocational Education and Training (TVET). By examining journal impact through these citation metrics, the analysis reveals key platforms where influential research is disseminated, offering insights into the visibility, credibility, and scholarly influence of studies related to AI in TVET.

This step is crucial as it enables researchers, policymakers, and practitioners to recognize the most authoritative journals in the field, thereby guiding future research dissemination and scholarly engagement (Donthu et al., 2021). Identifying highly cited journals also supports strategic publishing decisions for scholars aiming to contribute to impactful literature. Furthermore, understanding the citation distribution across sources aids in evaluating the advancement of AI applications within TVET and assessing interdisciplinary research trends (Aria & Cuccurullo, 2017).

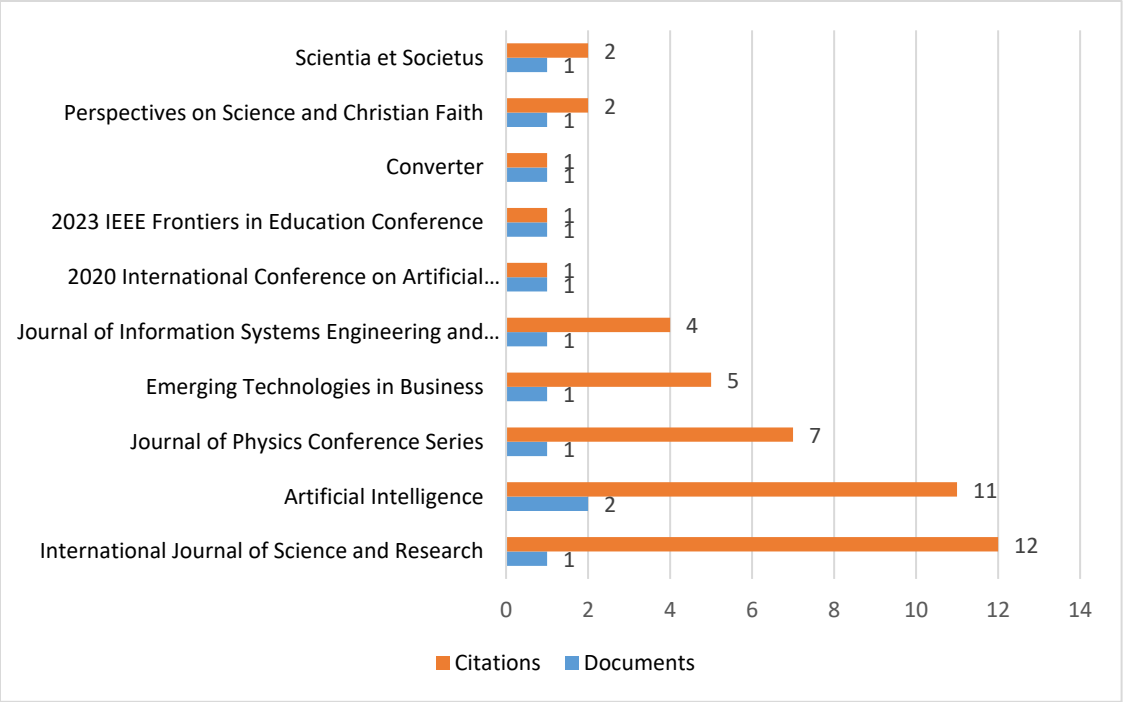
Among the 37 sources selected by VOSviewer, only 10 met the threshold for citation counts. Figure 3 presents the results of the analysis, including journal names, publication counts, and citation figures.

The top ten sources publishing on Artificial Intelligence (AI) in Technical and Vocational Education and Training (TVET) from 2015 to 2024 include a range of journals and conference proceedings. The *International Journal of Science and Research* has the highest citation count (12), indicating significant contributions to this field. The journal *Artificial Intelligence*, despite publishing only two documents, has received 11 citations, highlighting its relevance at the intersection of AI and TVET.

Other sources, such as the *Journal of Physics Conference Series* (7 citations) and *Emerging Technologies in Business* (5 citations), demonstrate the interdisciplinary nature of this research, linking AI with applied science and business contexts in TVET. The inclusion of preprints and region-specific journals, such as *Jurnal Dehasen Untuk Negeri* (4 citations) and the *Malaysian Journal of Information and Communication Technology* (4 citations), reflects growing global interest, particularly in developing regions.

Figure 3

Top 10 sources based on citation numbers with at least a publication AI in TVET within 2015 - 2024



These findings emphasize the increasing recognition of AI's role in transforming vocational education, with contributions from both international and regional platforms. High citation counts in interdisciplinary journals suggest that the exploration of AI in TVET involves perspectives from business, engineering, and technology. For researchers, this highlights the importance of engaging with journals that address cross-cutting themes, particularly where AI intersects with practical vocational training applications. The prominence of conference proceedings underscores the evolving nature of the field, where timely dissemination complements journal publications.

Additionally, the visibility of journals from developing countries indicates that AI in TVET is a relevant global issue, not confined to industrialized nations. Researchers and policymakers should consider localized solutions and culturally sensitive applications of AI in education. The data indicates a positive trajectory for AI in TVET research, with implications for interdisciplinary collaboration, innovative pedagogy, and the equitable development of AI-enabled vocational training systems worldwide.

Author Affiliations and their citations

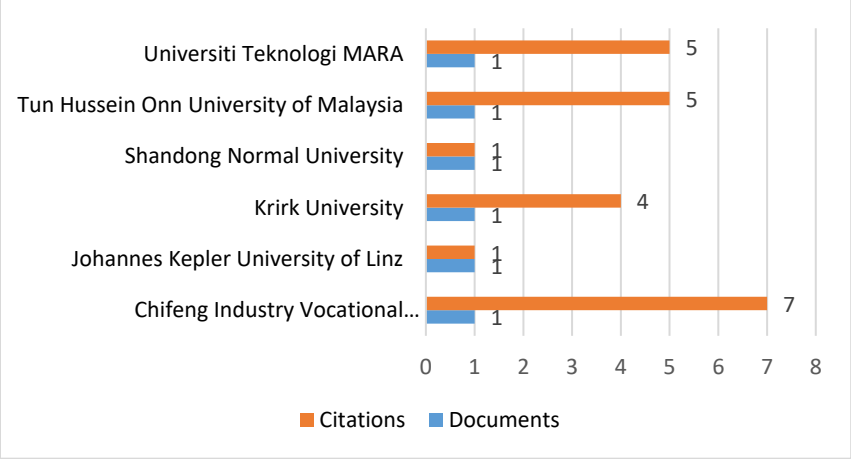
The publications were evaluated based on author affiliations to assess institutional contributions to research on Artificial Intelligence (AI) in Technical and Vocational Education and Training (TVET) from 2015 to 2024. This method is essential in bibliometric studies, as it helps identify the most active and influential institutions shaping the

research landscape in this field. Analyzing institutional affiliations highlights centers of academic excellence and uncovers patterns of collaboration, resource allocation, and regional leadership in emerging research domains. Evaluating institutional productivity and impact offers insights into the structural development of a field and informs decisions regarding academic networking and policy support. Thus, this analysis is crucial for understanding the institutional dynamics driving the integration of AI into TVET systems.

Among the 24 institutions assessed, only 6 met the threshold of having at least one citation. The results are presented in Figure 4.

Figure 4

Affiliations of authors in AI in TVET research and their citations for 2015 to 2024



The data provides insights into six key organizations contributing to the field of Artificial Intelligence (AI) in Technical and Vocational Education and Training (TVET) from 2015 to 2024. Each institution has authored a single publication; however, the number of citations for these works varies significantly, indicating differing impacts. The institution with the highest citation count is *Chifeng Industry Vocational Technology College* with seven citations, followed by *Tun Hussein Onn University of Malaysia* and *Universiti Teknologi MARA*, each with five citations. *Krirk University* has four citations, while *Johannes Kepler University of Linz* and *Shandong Normal University* each recorded one citation.

This data suggests that contributions to the intersection of AI and TVET are emerging from a diverse range of geographical and institutional contexts, encompassing universities in both Asia and Europe. Although each institution has published an equal number of works, the variation in citations implies differences in visibility, relevance, or influence of their research outputs. The higher citation counts for institutions such as Chifeng Industry Vocational Technology College and the Malaysian universities may indicate that their work resonates more strongly within the

academic community, potentially due to context-specific relevance, practical applications, or the novelty of the research themes explored.

The presence of Malaysian institutions among the top citation counts suggests that Southeast Asia is increasingly becoming a hub for research in AI and TVET. This highlights the region's growing academic engagement with technological innovation in vocational education. The implications of the data on author affiliations in AI and TVET research from 2015 to 2024 reveal several important trends and directions for the field. Firstly, institutions with higher citation counts, such as Chifeng Industry Vocational Technology College and the Malaysian universities, demonstrate a significant influence on the academic discourse surrounding AI in TVET. These institutions may serve as focal points for academic collaboration, offering mentorship and knowledge exchange opportunities. Their approaches and research methodologies could provide valuable insights for other institutions seeking to enhance their visibility and impact within the field.

Secondly, the prominence of Malaysian institutions among the top-cited highlights the increasing role of Southeast Asia in AI and TVET research. This regional leadership indicates a growing academic commitment to technological innovation in vocational education, potentially influencing national and regional education policies. Such momentum could attract further investments, policy support, and international partnerships aimed at advancing AI integration in TVET systems.

Another important implication pertains to equity in research impact. Although each institution produced one publication, the differing citation counts reflect variations in research relevance, quality, and dissemination strategies. This underscores the need for a more balanced approach to supporting institutions, particularly those with lower visibility, through capacity building, collaborative networks, and improved access to publication and dissemination platforms.

Finally, the results encourage institutions to align their research more strategically with global and regional priorities. Topics such as Industry 4.0, smart manufacturing, and digital workforce development are highly relevant to both AI and TVET. By focusing on these areas, institutions can enhance the applicability and influence of their research, contributing meaningfully to the evolving landscape of vocational education in the digital age.

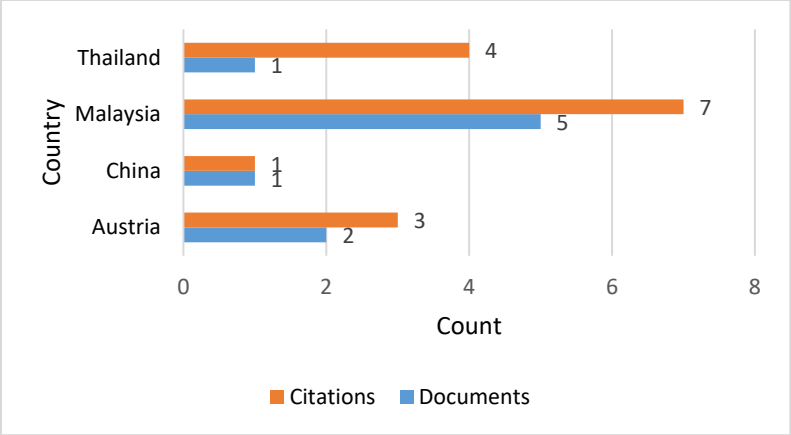
Countries' contribution to AI in TVET based on citations

The publications were evaluated based on each country's contributions to research on AI in Technical and Vocational Education and Training (TVET). This assessment aimed to identify geographical trends, recognize leading nations, and highlight regions needing increased research investment. This understanding reveals potential disparities in global research output, essential for fostering international collaboration, guiding policy, and promoting equitable AI development in TVET.

This approach is based on the principle that understanding the geographical distribution of research helps identify centers of excellence and underserved regions(Bornmann & Mutz, 2015). Mapping national contributions to research areas like AI in education is a common method in bibliometric studies to assess knowledge production and innovation capacity (Zupic & Cater, 2015). Among the nine countries selected by VOSviewer, only four met the threshold of at least one citation.

Figure 5

Countries' contribution to research on AI in TVET publications (with at least a citation)



Malaysia's prominent position in documents and citations reflects a strong emphasis on AI applications in Technical and Vocational Education and Training (TVET), supported by institutional backing and national policies aligned with the Industrial Revolution 4.0. In contrast, Thailand's high citation rates from fewer publications indicate impactful research quality. Austria shows moderate outputs, while China's low figures may suggest emerging interest or under-representation in the literature.

These findings position Malaysia as a regional leader in AI research within TVET, prioritizing AI integration in vocational education and becoming a candidate for academic collaboration. Other regions may benefit from benchmarking their strategies against Malaysia's. Although Thailand has fewer publications, its performance demonstrates that significant contributions can emerge from smaller research bases. The high citation count highlights the advantage of producing fewer but high-quality studies over generating a large volume of low-impact work (Ivanović & Ho, 2019). China and Austria, despite their potential, show lower engagement in AI and TVET scholarship, indicating missed opportunities. Encouraging greater participation from these and other underrepresented countries could enhance global diversity in AI integration into vocational training.

Ultimately, the results underscore the need for aligning policy and funding with research objectives. Governments and educational institutions should increase investments in AI and TVET research, particularly in regions with low output, to foster innovation and ensure vocational education systems remain relevant in the context of Industry 4.0.

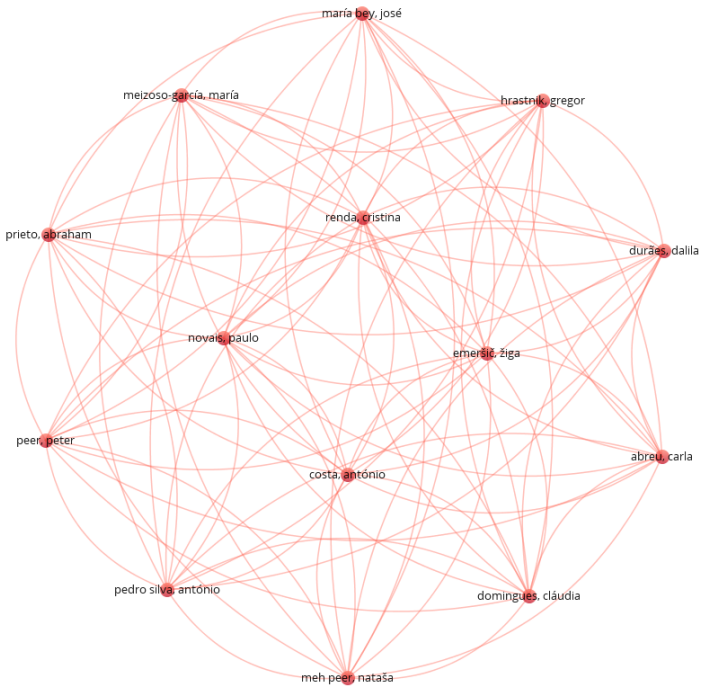
Co-authorship and citations

A VOSviewer visualization network was developed to analyze co-authorship and citations, focusing on collaborative relationships among researchers and identifying influential authors and institutional connections within the field of Artificial Intelligence (AI) in Technical and Vocational Education and Training (TVET). This methodology uncovers patterns of scholarly collaboration, highlights key contributors, and illustrates the dissemination of knowledge throughout the research landscape. The analysis aids in identifying central figures, potential research clusters, and the overall structure of the research community.

This research approach underscores the significance of mapping scientific collaboration and influence to understand the evolution of research fields and to identify areas where future collaborations may be most effective. Visualization tools such as VOSviewer enhance traditional bibliometric analysis by providing graphical representations of complex networks, thereby facilitating the identification of research trends and relationships (van Eck & Waltman, 2010). Co-authorship networks also offer insights into the social structure of scientific communities, enabling the evaluation of the maturity and connectivity of a research field (Glänzel & András Schubert, 2004). Among the 111 authors identified by VOSviewer, only 28 met the criterion of at least two citations. The results is presented in Figure 5.

Figure 6

Network visualization of co-authorship and citations for publications in AI in TVET



The VOSviewer visualization in Figure 6 illustrates a co-authorship network in Artificial Intelligence (AI) within Technical and Vocational Education and Training (TVET). Key figures such as *Renda Cristina, Costa António, Novais*

Paulo, and *Emeršič Žiga* show significant collaboration and influence. The network's density indicates a strong collaborative environment, with robust links among researchers from various institutions and regions. The red lines represent co-authorship links, with the thickness and proximity of nodes reflecting collaboration strength and frequency. Clusters of authors suggest active research teams. The central positioning of certain nodes indicates key connectors or hubs in the academic community. This co-authorship map points to a mature and expanding research domain prioritizing collaboration. Authors like *Renda Cristina, Costa António*, and *Emeršič Žiga* are influential thought leaders in AI and TVET.

The distribution of authors and clusters suggests potential regional or institutional collaborations, driven by interdisciplinary or international research initiatives. The presence of diverse authors indicates that AI in TVET transcends a single academic tradition, evolving into an interdisciplinary and global research agenda (Rosyadi et al., 2023). The visualization underscores the importance of collaborative research efforts, as strong interconnections among authors highlight the necessity of partnerships and teamwork for advancing knowledge in this area. The central roles of certain authors suggest they act as key influencers and thought leaders, shaping research directions, mentoring emerging scholars, and facilitating collaborations. Recognizing these central figures is vital for stakeholders seeking strategic partnerships or experts to guide educational reforms and digital transformation in TVET.

Insights from the co-authorship network are invaluable for research funders and policymakers. Identifying productive and collaborative clusters allows funding agencies to allocate resources effectively and support innovative projects. This informed investment can accelerate advancements in AI-driven TVET practices. The network also highlights opportunities for enhancing inclusivity in research; less connected authors or regions may benefit from targeted capacity-building initiatives. Supporting these efforts can promote a more balanced global research landscape, ensuring equitable benefits from AI integration in TVET across various educational and socio-economic contexts.

Institutional co-authorship with publications on AI and TVET from 2015-2024

The study examined institutional co-authorship to elucidate collaborative research patterns and their effects on academic productivity. Institutional co-authorship signifies research collaboration, emphasizing the interconnectedness among researchers and institutions within a specific academic network (Glänzel & András Schubert, 2004). This collaboration is essential for knowledge exchange and enhancing the visibility of research outputs (Aria & Cuccurullo, 2017). Analyzing institutional co-authorship offers insights into the distribution of research contributions and the extent of interdisciplinary engagement among institutions. As collaborative research becomes increasingly significant in academia, evaluating institutional co-authorship reveals how institutions align their research efforts for greater impact and recognition.

Among the 24 institutions identified by VOSviewer for institutional co-authorship, only six met the criteria of having at least one publication and citation. This is presented in Table 4.

Table 4

Institutional co-authorship with publications on AI and TVET from 2015-2024

Organization	Documents	Citations
Tun Hussein Onn University of Malaysia	1	5
Universiti Teknologi MARA	1	5
Chifeng Industry Vocational Technology College	1	7
Johannes Kepler University of Linz	1	1
Krirk University	1	4
Shandong Normal University	1	1

The data on institutional co-authorship in AI and TVET research reveals collaboration patterns among universities and institutions. This analysis examines how different organizations contribute to academic discourse through research publications, providing insights into their academic influence and networking capabilities. Findings indicate that each institution contributed one research document; however, citation counts vary significantly. *Chifeng Industry Vocational Technology College* leads with the highest citation count of seven, demonstrating a notable impact from its singular document. *Tun Hussein Onn University of Malaysia* and *Universiti Teknologi MARA* each have five citations, reflecting the strong standing of their work in academic circles. *Krik University* follows with four citations, indicating moderate influence. In contrast, *Johannes Kepler University of Linz* and *Shandong Normal University* each have only one citation, suggesting limited visibility or recent contributions that have yet to gain recognition.

The variation in citation counts underscores that institutional reputation, research quality, and collaborative networks are key determinants of the impact of academic work. Institutions with higher citation counts likely engage in research that resonates with the academic community or aligns with current trends in AI and TVET. The presence of multiple institutions from *Malaysia* and *China* further illustrates the active involvement of these regions in AI and TVET research and their efforts to foster international collaborations. This analysis of institutional co-authorship provides valuable insights into academic influence and collaboration dynamics. Institutions with high citation counts should be regarded as potential research partners due to their recognized impact. Conversely, universities with lower citation counts could benefit from strategic collaborations with high-impact institutions to enhance their visibility and research influence.

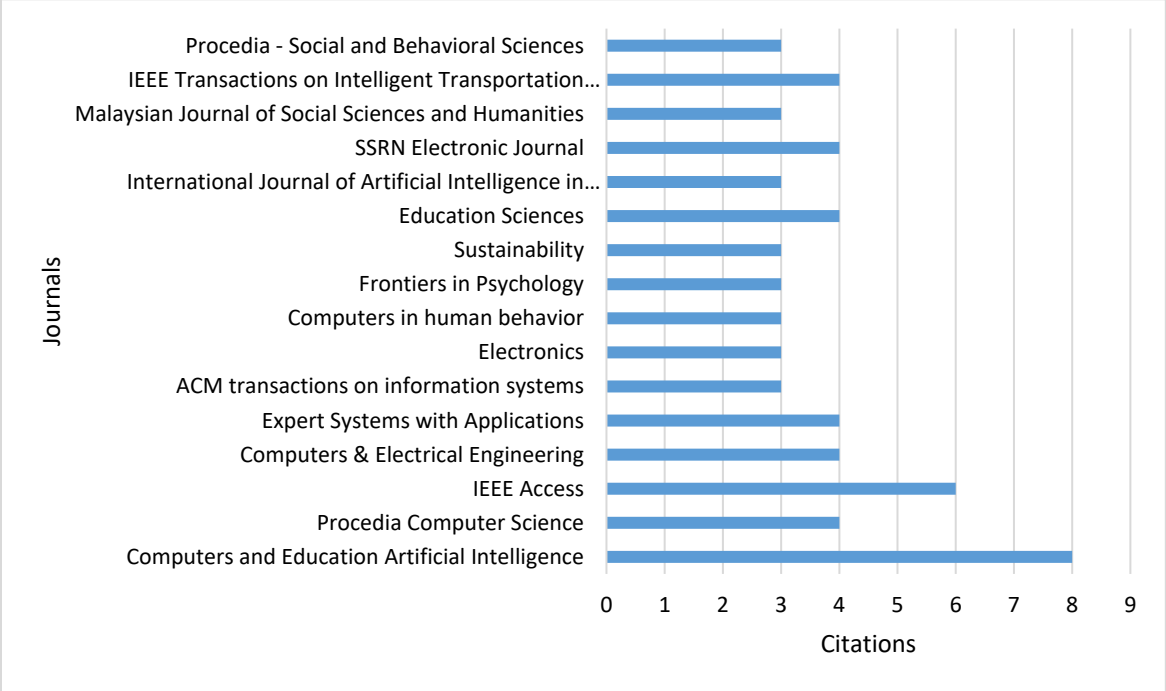
Ultimately, this analysis emphasizes the importance of institutional networks in amplifying research impact. Institutions with strong collaborative ties tend to achieve greater recognition, making co-authorship a crucial factor in enhancing research output. In the fields of AI and TVET, promoting more institutional collaborations across countries could lead to greater knowledge sharing, improved research quality, and higher citation impact. The data illustrates the varying levels of research influence among institutions and the value of strategic academic partnerships in AI and TVET research. Strengthening co-authorship networks can assist institutions in enhancing their visibility and contributing more significantly to the evolving landscape of AI-driven education and vocational training.

Co-citations and cited journals

The study investigated co-citations among journals to analyze the intellectual structure and scholarly influence within the field. Co-citation analysis assesses the relationships among academic works and facilitates the understanding of the evolution of research domains (Suharso et al., 2021). This method identifies key sources of knowledge, emerging research trends, and thematic connections among publications (Chen et al., 2022). By analyzing co-cited journals, the study aims to map influential research and provide insights into how knowledge dissemination shapes academic discourse. The selection of co-citation analysis is substantiated by its effectiveness in revealing patterns of scholarly communication and tracing the historical development of research topics (Santana & Díaz-Fernández, 2023). This approach also aids in identifying core journals within the academic landscape, ensuring a comprehensive understanding of foundational literature in the field (Zupic & Čater, 2015). Among the 253 journals selected by VOSviewer, 17 met the threshold for co-citations, each receiving at least three citations.

Figure 7

Co-citations of cited journals on AI in TVET with at least three citations



The co-citation analysis identifies the most frequently referenced sources in artificial intelligence (AI) research related to Technical and Vocational Education and Training (TVET). The journal *Computers and Education Artificial Intelligence* emerges as the most cited source, with eight mentions, followed by *IEEE Access* with six citations. Other notable sources include *Computers & Electrical Engineering*, *Expert Systems with Applications*, *Procedia Computer Science*, and *Education Sciences*, each cited four times. Additionally, journals such as *ACM Transactions on*

Information Systems, *Electronics*, *Computers in Human Behavior*, and *Frontiers in Psychology* each received three citations, indicating their relevance in interdisciplinary AI applications. The inclusion of journals like *Sustainability* and *Social Sciences* reflects a growing interest in the impact of AI on environmental and societal issues.

The diversity of cited sources underscores the interdisciplinary nature of AI research in TVET. The representation of psychology, human behavior, and sustainability journals suggests an increasing acknowledgment of the broader implications of AI integration in education. Furthermore, the presence of engineering and computing journals highlights a focus on AI-driven automation and intelligent systems within vocational education.

These findings carry significant implications for policy and curriculum development in TVET. The varied range of cited sources indicates that AI should be integrated into vocational education curricula beyond technical subjects, incorporating ethical, psychological, and sustainability considerations. Moreover, the results reveal future research opportunities, particularly in exploring AI's psychological, behavioral, and societal impacts in TVET to enhance adoption and effectiveness. The intersection of AI with education, human behavior, and sustainability presents prospects for cross-disciplinary collaboration, paving the way for a more holistic approach to AI implementation in TVET research and practice.

Bibliographic coupling and countries

Bibliographic coupling is a method used in bibliometric analysis to measure the degree of similarity between two or more research publications based on their shared references. When two documents cite the same sources, they are considered bibliographically coupled, indicating a conceptual or thematic connection in their research focus (Ebrahim, 2017). This method helps in mapping research networks, identifying emerging trends, and understanding the intellectual structure of a given field.

The significance of bibliographic coupling lies in its ability to highlight research collaboration patterns and the evolution of academic discourse. By analyzing how countries, are interconnected through shared references, scholars can pinpoint influential works and assess the impact of different research contributions. In fields such as Artificial Intelligence (AI) and Technical and Vocational Education and Training (TVET), bibliographic coupling can reveal which nations are leading in innovation, where impactful studies are originating, and how research themes evolve over time (Santana & Díaz-Fernández, 2023).

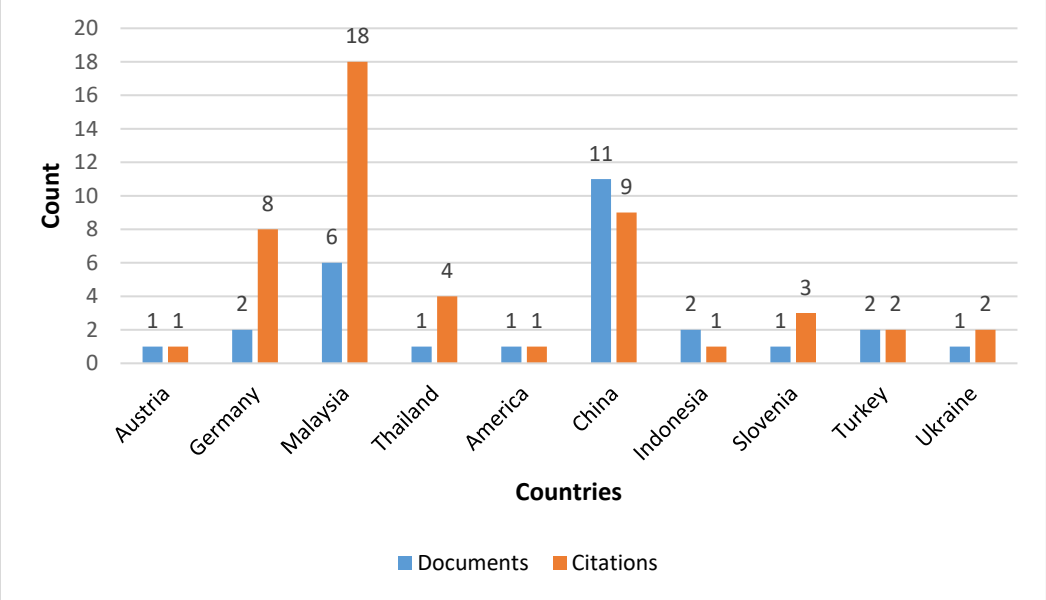
For policymakers and funding agencies, bibliographic coupling serves as a crucial tool for strategic decision-making. It enables them to allocate resources efficiently, foster international collaborations, and support high-impact research initiatives. In AI and TVET research, understanding bibliographic relationships can help in identifying key players, improving knowledge dissemination, and enhancing cross-border academic cooperation (van Eck & Waltman, 2014).

Given the importance of bibliographic coupling in mapping academic influence and intellectual connections, this study examines how different countries contribute to AI and TVET research through bibliographic relationships and

citations. The following analysis presents data on the number of research documents and their citations, providing insights into the global research landscape in this field. Of the 20 countries, 10 met the threshold of countries with at least a publication on AI in TVET.

Figure 8

Bibliographic coupling analysis of countries' research on AI in TVET for 2015 – 2024



The bibliographic coupling analysis of artificial intelligence (AI) and technical and vocational education and training (TVET) research from 2015 to 2024 provides valuable insights into the contributions of various countries. The data illustrates the number of research documents produced by each country alongside their corresponding citations, highlighting both productivity and impact.

China emerges as the leading contributor with eleven documents; however, it has only nine citations, indicating a moderate impact per publication. Malaysia, with six documents and eighteen citations, demonstrates a high level of influence despite a lower publication count. Germany, with two documents, received eight citations, underscoring the quality of its research output. Thailand, Slovenia, and Ukraine each produced one document but garnered significant citations, reflecting valuable contributions. Indonesia and Turkey each published two documents, with Turkey slightly surpassing Indonesia in citation count. Austria and the United States contributed one document each, with a single citation, indicating a lower influence in this domain.

These findings reveal a distinction between the quantity and quality of research. While China leads in publication volume, countries such as Malaysia and Germany exhibit a stronger citation impact per paper, suggesting their research is more widely recognized. This indicates that research impact is contingent upon both publication volume

and the relevance of the work. The implications of this analysis are significant for researchers, policymakers, and academic institutions. Countries with high research impact but fewer publications, like Malaysia and Germany, may benefit from increased funding to expand their efforts. Conversely, China's extensive output positions it as a key player in AI and TVET, making it an attractive partner for collaboration. Emerging research hubs, such as Indonesia and Slovenia, could enhance their impact through strategic partnerships. This analysis underscores the varying contributions of nations to AI and TVET research. By considering both research output and citation impact, institutions and policymakers can gain a clearer understanding of global research trends and identify opportunities for collaboration and investment.

Keywords and Emerging Research Themes

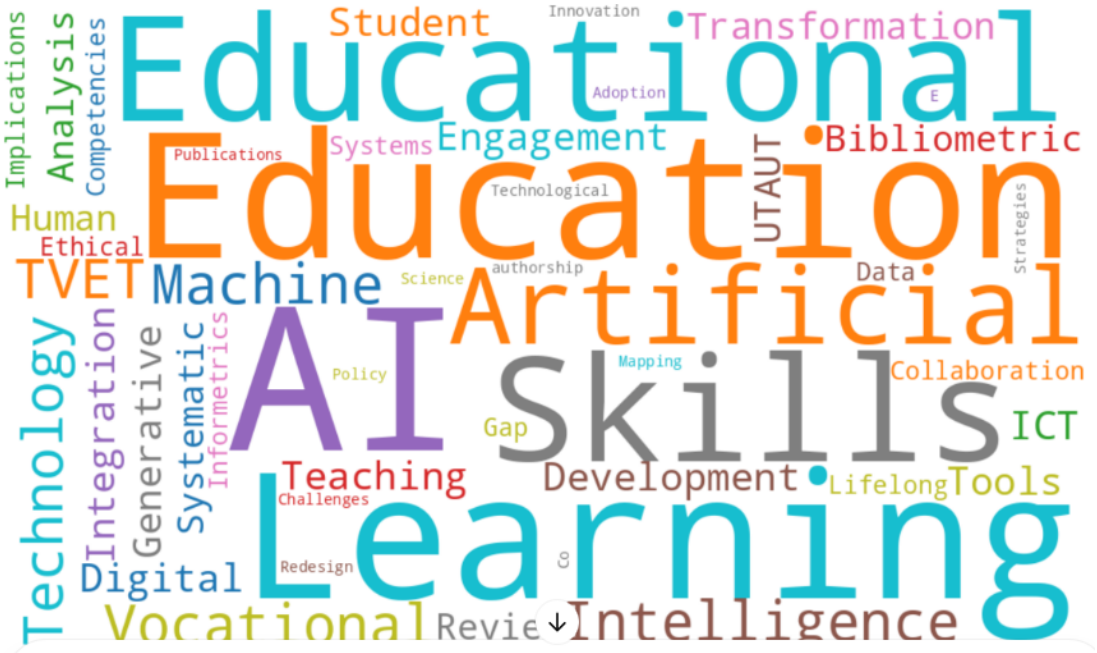
Word cloud was generated from the scholarly literature on AI research in TVEt to identify the keywords and emerging research themes in the field. The word cloud, as presented in Figure 9, illustrated a dynamic landscape of emerging research themes at the intersection of Artificial Intelligence and TVET. The frequency and prominence of terms highlight key areas of focus and trends shaping this field.

Central to the word cloud are significant terms such as "Artificial Intelligence," "Education," and "TVET," emphasizing the primary concern: integrating AI technologies into vocational learning environments. This reflects a transition toward smart education systems aimed at enhancing efficiency, adaptability, and innovation in skill development. Terms like "students," "learning," "engagement," and "skills" indicate a growing interest in learner-centered approaches. Research is concentrated on how AI can personalize learning pathways, accommodate diverse needs, and enhance motivation—particularly in skills-based education, where individual pacing and competency levels vary.

The cluster of terms surrounding "teaching," "pedagogy," and "curriculum" underscores how AI is redefining instructional design and delivery. Scholars are investigating how educators can leverage intelligent systems to co-create content, automate assessments, and provide real-time feedback, particularly in hands-on subjects. Keywords such as "UTAUT," "adoption," "acceptance," and "readiness" signify research activity focused on technology uptake frameworks. Studies are exploring the factors that facilitate or hinder AI adoption in vocational contexts, employing models like the Unified Theory of Acceptance and Use of Technology (UTAUT). This research is essential for understanding institutional preparedness and user attitudes toward AI.

Figure 9

Word cloud on keywords and emerging themes on AI in TVET research



The frequent appearance of terms like "skills," "competence," and "digital" highlights a focus on workforce transformation. This research connects AI-enhanced learning with Industry 4.0 skills, linking educational innovation with employability and labour market demands. Terms such as "technology," "systems," and "tools" reflect the engineering and design aspects of AI in TVET. This involves developing AI-powered platforms, learning management systems (LMS), and intelligent tutoring systems tailored for vocational training—particularly those capable of simulating real-world scenarios.

Smaller yet significant terms like "ethics," "sustainability," and "inclusion" indicate an emerging discourse surrounding the responsible use of AI. Research is beginning to address issues related to algorithmic bias, data privacy, and equitable access, ensuring that AI deployment in TVET does not exacerbate digital divides.

Table 5

Summary of emerging research themes, key focus, keywords and key publications on AI in TVET

Theme	Key Focus	Keywords	Publications
AI-Powered Learning Environments	Smart, adaptive, data-driven platforms for TVET	Artificial Intelligence, Education, Technology	Ali et al. (2024); Rosyadi et al. (2023); Chen et al. (2022)
Personalized and Engaging Learning	Student-centered, autonomous learning	Learning, Students, Engagement	Panigrahi et al. (2021); Wayne et al. (2019); Baharin et al. (2025)
Pedagogical Innovation	Curriculum design, AI in instruction	Teaching, Pedagogy, Curriculum	Ali et al. (2024); Zawacki-Richter et al. (2019); Teo et al. (2016)
Adoption and Acceptance	Barriers/enablers of AI use in education	UTAUT, Adoption, Readiness	Baharin et al. (2025); Donthu et al. (2021); Koseoglu (2016)
Skill Development for Industry 4.0	Digital and cognitive competencies	Skills, Competence, Digital	Shiohira (2021); Santana & Díaz-Fernández (2023); UNESCO (2016)
AI Infrastructure and Tools	Platform development and tech integration	Systems, Tools, Models	Aria & Cuccurullo (2017); Hook et al. (2021); Suharso et al. (2021)
Ethical and Inclusive Implementation	Fairness, transparency, sustainability	Ethics, Inclusion, Equity	Skerritt (2023); Jiang et al. (2023); UNESCO (2019)

Discussions and Implications

The findings of this study indicate a significant increase in AI-TVET research, reflecting global efforts toward digital transformation in education. This growth aligns with existing literature that emphasizes AI's role in personalizing learning and enhancing the efficiency of educational systems (Holmes et al., 2019). Bibliometric analysis reveals concentrated authorship in specific regions and emerging themes such as automation and personalized learning, consistent with earlier studies that identified geographical imbalances and thematic silos in EdTech research (Zawacki-Richter et al., 2019).

This study uniquely examines how AI applications in TVET differ from broader trends in educational technology. Unlike higher education, which often employs AI for content delivery and assessment, TVET necessitates more hands-on and simulation-based AI interventions. However, simulation technologies and virtual reality, which are essential for practical training, remain underrepresented in current research, indicating a disconnect between available technologies and the pedagogical needs of TVET.

The increase in AI-TVET publications since 2019 indicates a significant shift beyond mere incremental growth; it suggests that the field is entering a *pre-paradigmatic expansion phase* (Kuhn, 1962). This rapid rise in output aligns with structural factors such as national AI funding initiatives, digital transformation driven by the pandemic, and the

emergence of generative AI following the introduction of large language models. These external influences often catalyze exploratory research before theoretical frameworks are established (Porter & Rafols, 2009).

The concentration of citations around a limited number of foundational works underscores the early-stage intellectual structuring within the field. According to Price's Law (Price, 1963), a small number of influential publications disproportionately affect knowledge production in emerging areas. Co-citation patterns indicate a reliance on general AI-in-education literature rather than a distinct theoretical framework specific to AI-TVET. Small's (1973) co-citation theory suggests that stable and diverse citation clusters reflect cognitive maturity. The relatively centralized citation structure indicates that AI-TVET has not yet developed differentiated theoretical schools.

Moreover, the fragmented nature of collaboration networks highlights structural disunity. Science mapping theory (van Eck & Waltman, 2010) connects dense international collaboration and cohesive clusters with field maturity. The uneven geographic distribution observed in this study reveals disparities in research capacity and AI infrastructure across various regions.

Overall, these scientometric trends suggest that AI-TVET is transitioning from exploratory experimentation toward the potential establishment of a paradigm. However, the field remains heavily reliant on related domains for theoretical guidance. Future research should prioritize the development of vocationally grounded AI theory to promote intellectual consolidation and enhance policy relevance.

The policy implications are significant. First, governments and education ministries should prioritize investments in AI infrastructure tailored for vocational settings, including digital labs and simulation platforms. Second, training educators to effectively utilize AI tools must become a primary policy objective, necessitating capacity building and curriculum integration. Third, policies should promote equitable access to AI technologies, particularly for rural and marginalized learners, to ensure they acquire industry-relevant skills.

The bibliometric analysis indicates a substantial increase in publications related to AI in Technical and Vocational Education and Training (TVET) post-2019, reflecting significant transformations within global education systems. This growth is closely associated with the rapid digital transformation that occurred during the COVID-19 pandemic, alongside the pressing need to cultivate a workforce adept for Industry 4.0. Consequently, the integration of artificial intelligence in TVET serves as a strategic response to economic changes.

Key themes identified, such as "intelligent tutoring systems," "adaptive learning," and "automation skills," signify a transition from traditional competency-based instruction toward data-driven personalization and predictive analytics within vocational education. Nevertheless, the limited emphasis on ethics, algorithmic bias, and inclusivity reveals a critical gap in AI literacy within the scope of TVET research.

The predominance of publications originating from technologically advanced economies highlights an uneven global engagement in AI-TVET research, raising important policy considerations regarding digital infrastructure, capacity building, and equitable AI adoption in developing TVET systems. The bibliometric trends suggest that AI-TVET research is progressing from exploratory experimentation to systemic transformation, although there remains a disparity in critical and policy-oriented engagement.

AI integration in TVET should be viewed as a sociotechnical transformation rather than a purely technological advancement. Sociotechnical systems theory highlights the co-evolution of technologies, institutional frameworks, workforce policies, and human competencies. In vocational education—where training is closely aligned with occupational standards and labor market needs—technological changes inevitably reshape curricula, assessment models, teacher expertise, and industry partnerships.

The post-2019 increase in AI-TVET publications reflects systemic alignment pressures driven by national AI strategies, Industry 4.0 skill agendas, and the digital acceleration prompted by the pandemic. Consequently, AI adoption in TVET necessitates the reconfiguration of competency-based training and workplace simulation models, rather than simply the introduction of new digital tools.

The geographic concentration of research output further illustrates an uneven sociotechnical capacity. Regions with robust AI funding ecosystems and industrial infrastructures lead in knowledge production, while others remain at a disadvantage. Additionally, the field's reliance on broader AI-in-education literature suggests that AI-TVET has yet to establish a distinct vocational theoretical foundation. Future research must intentionally integrate vocational learning theory and skills formation frameworks to enhance intellectual development and policy relevance.

Vocational education institutions should adopt a strategic approach to AI integration. This involves piloting AI applications in specific trades, measuring outcomes, and scaling successful initiatives based on empirical evidence. Collaboration with industry partners can ensure that AI-driven TVET programs align with labour market needs. The bibliometric trends highlight the importance of cross-sector collaboration, encouraging practitioners to co-develop scalable, ethical, and impactful AI solutions. By emphasizing both progress and existing gaps, this study establishes a foundation for reimagining how AI can support skill development in inclusive, context-sensitive, and future-ready manners.

Knowledge Gaps and Future Research

The bibliometric analysis reveals a growing body of research focused on the applications of Artificial Intelligence (AI) in Technical and Vocational Education and Training (TVET), particularly since 2019. However, this emerging field remains fragmented and lacks comprehensive theoretical frameworks in several critical areas. A significant knowledge gap exists in longitudinal and impact-based studies that assess the effectiveness of AI-driven interventions in real-world TVET environments. Although keyword analysis indicates interest in adaptive learning, intelligent tutoring, and automation, there is insufficient empirical research to validate the effectiveness of these technologies in enhancing practical skills acquisition or improving employability outcomes.

Another underexplored aspect is the ethical and equity implications of AI use in vocational education. Issues related to data privacy, algorithmic bias, and digital exclusion are largely neglected in the literature. The focus has primarily been on technological potential rather than pedagogical suitability or contextual adaptation, particularly in low-resource and developing country contexts. Furthermore, the integration of AI with traditional TVET practices—such as apprenticeships and workshop-based training—has not been rigorously examined, resulting in a methodological gap in understanding blended or hybrid models of AI and TVET.

Future research should adopt a multidisciplinary approach that incorporates technical, educational, and sociological perspectives. Comparative studies between high-income and low-income contexts could illuminate how infrastructural differences influence AI adoption in TVET. Additionally, it is crucial to investigate the roles of teacher training, organizational readiness, and curriculum reform in facilitating sustainable AI integration. Predictive analytics and learning analytics represent another area for exploration, where future studies can evaluate how AI-driven insights can personalize vocational learning pathways and reduce dropout rates. Moreover, policy-oriented research should analyze regulatory frameworks, funding mechanisms, and public-private partnerships to support the ethical deployment of AI in skills development.

Conclusions

This study highlights a significant increase in interest in integrating Artificial Intelligence (AI) within Technical and Vocational Education and Training (TVET). However, it identifies critical gaps in the literature, such as limited empirical validation of AI tools in real-world TVET environments and a lack of attention to contextual, ethical, and infrastructural factors. These findings have important implications for research and policy.

Future studies should focus on longitudinal evaluations of AI's effects on skill development, learning outcomes, and employability. There is also a strong need for cross-cultural and comparative research to explore AI-TVET dynamics in varied socio-economic contexts. Employing multidisciplinary approaches will be crucial in aligning technological potential with pedagogical relevance.

The findings advocate for a structured strategy for AI integration in vocational training. This strategy should include investments in AI infrastructure suitable for hands-on skills training, frameworks to support teacher preparedness, and policies that ensure equitable access to AI-driven learning. Additionally, public-private partnerships and regulatory guidelines should be developed to promote responsible, ethical, and scalable implementation of AI in TVET. These recommendations provide a roadmap for creating an AI-enhanced TVET system that is inclusive, adaptable, and future-focused.

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