Social Sciences & Humanities Open 11 (2025) 101401

Contents lists available at ScienceDirect

Social Sciences & Humanities Open

journal homepage: www.sciencedirect.com/journal/social-sciences-and-humanities-open

Review Article

Harnessing artificial intelligence to revolutionize vocational education: Emerging trends, challenges, and contributions to SDGs 2030

Febri Prasetya [a,*], Aprilla Fortuna [a], Agariadne Dwinggo Samala [a], Dinda Khaira Latifa [b], Welli Andriani [c], Utari Akhir Gusti [c], Muhammad Raihan [a], Santiago Criollo-C [d], Deniz Kaya [e], Juan Luis Cabanillas García [f]

[a] Faculty of Engineering, Universitas Negeri Padang, Indonesia, Jalan Prof. Dr. Hamka, Air Tawar Padang, 25132, Sumatera Barat, Indonesia
[b] Technology and Vocational Education, Universitas Negeri Yogyakarta, Indonesia, Jl. Colombo No.1, Karang Malang, Caturtunggal, Kec. Depok, Kabupaten Sleman, Daerah Istimewa Yogyakarta 55281, Indonesia
[c] Faculty of Mathematics and Natural Sciences Education, Universitas Pendidikan Indonesia, Indonesia, Jalan. Dr. Setiabudi No.229, Isola, Kec. Sukasari, Kota Bandung, Jawa Barat, 40154, Indonesia
[d] Facultad de Ingeniería y Ciencias Aplicadas, Universidad de Las Américas, Quito 170125, Ecuador, De Los Colimes esq, Quito, 170513, Ecuador
[e] Faculty of Education, Nevşehir Hacı Bektaş Veli University, Turkey, 2000 Evler, Zübeyde Hanım Cd., 50300, Merkez/Nevşehir Merkez/Nevşehir, Turkey
[f] Department of Didactics, Organization and Research Methods, Universidad de Extremadura, Av. de Elvas, s/n, 06006, Badajoz, Spain

ARTICLE INFO

Keywords:
Artificial intelligence
Media technology
Quality education
Sustainable development goals
Vocational education

ABSTRACT

This study conducts a bibliometric analysis of recent trends and emerging topics in the application of Artificial Intelligence (AI) in vocational education. AI technology holds significant potential to enhance accessibility, inclusivity, and equity in quality education. The research utilizes the Preferred Reporting Items for Systematic Reviews and Meta-Analyses approach to analyze publications from articles and conference papers published in the Scopus database between 2014 and 2023. The key findings indicate that AI is reshaping vocational education by personalizing learning experiences, improving curriculum development, and enhancing practical training through automation and robotics, particularly in the manufacturing and logistics sectors. Ethical issues, such as privacy and algorithmic bias, are also highlighted as key concerns. The bibliometric analysis reveals that journal articles have a higher citation count than conference papers, reflecting their greater influence in the field. Network visualization demonstrates the interconnection between AI, vocational education, and related concepts, such as e-learning and machine learning. Furthermore, AI contributes to the achievement of the United Nations Sustainable Development Goals (SDGs) 2030, particularly SDG 4 (quality education access), SDG 8 (decent work and economic growth), and SDG 9 (industry, innovation, and infrastructure). The study also identifies challenges that need to be addressed, including data privacy, infrastructure readiness, and teacher training, while providing guidance for future research and educational policy development.

1. Introduction

Artificial Intelligence (AI) is recognized as a pivotal technology with transformative potential across various sectors, including technical vocational education and training (Adel, 2024; Sandhu et al., 2024). In recent years, AI applications have increasingly influenced how vocational training programs are designed, delivered, and optimized (Ran & Han, 2023, pp. 1024–1028; Shen et al., 2024, pp. 111–119). As we progress towards achieving the Sustainable Development Goals (SDGs) by 2030, integrating AI in vocational training becomes crucial for addressing global challenges such as poverty alleviation, sustainable economic growth, and decent work for all (Odo, 2023; Ojeaga & Dumbiri, 2023; Sutikno, 2024). AI-driven solutions can be pivotal in democratizing access to quality education and providing scalable and cost-effective training solutions that reach underserved populations (Javaid et al., 2023). Additionally, AI can enhance job-matching processes, improve workforce readiness, and support continuous learning and skill development (Garlinska et al., 2023). By aligning vocational training with the latest technological advancements and industry needs, AI can help create more resilient and adaptable workforces.

* Corresponding author.
E-mail address: febriprasetya@ft.unp.ac.id (F. Prasetya).

https://doi.org/10.1016/j.ssaho.2025.101401
Received 5 November 2024; Received in revised form 25 January 2025; Accepted 1 March 2025
Available online 27 March 2025

Vocational training plays a significant role in equipping individuals with skills essential for sustainable development and inclusive growth (Fortuna, Prasetya, Luis, et al., 2024; Fortuna, Prasetya, Samala, et al., 2024; Prasetya et al., 2023; Wulansari et al., 2024). Artificial Intelligence (AI) is recognized as a transformative technology that significantly impacts vocational education and contributes to aligning educational practices with the Sustainable Development Goals (SDGs). According to Vinuesa et al. (2020) emphasize the potential of AI to enhance accessibility and quality in education, highlighting its pivotal role in fostering inclusive learning environments. Similarly, research by Adel (2024) argues that AI is transforming educational processes and is a critical tool in transitioning from Industry 4.0 to Industry 5.0. AI enables the creation of personalized learning experiences by tailoring educational content to individual learners' needs. According to Bhutoria (2022), a comparative study of the United States, China, and India discusses how AI-based educational approaches support personalized learning and thus contribute to increasing inclusiveness in education. By leveraging AI technologies, educators can provide real-time feedback and adaptive learning pathways that cater to diverse learning styles and paces, thereby improving educational outcomes and accessibility for all.

AI technologies offer promising opportunities to enhance the effectiveness, accessibility, and relevance of vocational education, thereby contributing to the attainment of SDGs related to quality education (SDG 4), decent work and economic growth (SDG 8), and industry, innovation, and infrastructure (SDG 9) (Mhlanga, 2023; Vinuesa et al., 2020). By integrating AI, vocational training programs can become more personalized, catering to individual learning needs and pacing (Bhutoria, 2022). This technology can also facilitate real-time feedback and adaptive learning pathways, ensuring learners acquire competencies more efficiently. Furthermore, AI can help bridge the gap between industry requirements and educational outcomes by continuously updating curriculum content based on current job market trends and technological advancements (Renz & Hilbig, 2021).

AI contributes significantly to developing vocational education programs and ensures these programs are aligned with labour market demands. For instance, finding by Javaid et al. (2023) explore the use of AI in Industry 4.0 applications and vocational education, underscoring its relevance in achieving SDGs 4 and 8. The study by Mhlanga (2023) also examines the impact of AI on digital transformation and sustainable development, noting that AI is critical in establishing a sustainable educational infrastructure that supports long-term development goals. The study by Prasetya, Fortuna, Samala, et al. (2024) examined the impact of technology-based learning experiences on student motivation. The findings indicated that technology positively influences student attention, material relevance, confidence building, and overall satisfaction.

A comprehensive understanding of current trends and emerging topics in AI for vocational training is essential for stakeholders, policymakers, and educators to leverage AI effectively in educational practices aligned with the SDGs 2030. A bibliometric analysis provides a systematic approach to exploring the scholarly landscape, identifying key research themes, influential publications, and gaps in knowledge (Renz & Hilbig, 2021). Such insights can inform evidence-based decision-making, policy formulation, and strategic investments in AI-driven vocational training initiatives (Muskhir et al., 2024; Prasetya, Fortuna, Jalinus, et al., 2024; Rahim et al., 2024). This approach ensures that vocational training programs remain relevant, efficient, and capable of meeting the evolving demands of the global workforce.

This study contributes to the existing literature by providing a comprehensive bibliometric analysis of publications on AI in vocational training. This study aims to map the evolution of AI applications in vocational training literature by conducting a comprehensive bibliometric analysis that integrates the SDGs framework. It seeks to identify research gaps, highlight impactful contributions, and uncover emerging areas of interest that align with sustainable development objectives. Ultimately, this research aims to guide future research agendas and educational policies aimed at harnessing AI to foster inclusive and equitable vocational training opportunities, thereby contributing to the broader agenda of sustainable development by 2030. On the whole, this study in formulating some innovative research questions designed to answer the objectives of this study:

RQ1. What are the current trends and emerging Artificial Intelligence (AI) topics for vocational training in the past decade (2014–2023)?
RQ2. Who are the top 10 most cited authors on Artificial Intelligence (AI) for vocational education over the past decade?
RQ3. What are the key themes and clusters of keywords in the academic literature on Artificial Intelligence (AI) in vocational education, as identified through VOSviewer analysis?
RQ4. How can Artificial Intelligence (AI) help achieve the Sustainable Development Goals (SDGs 2030), particularly vocational education?
RQ5. What are the challenges and opportunities of utilizing Artificial Intelligence (AI) technology in vocational education?
RQ6. What are the implication, limitation, and future prospects of emerging Artificial Intelligence (AI) technology in vocational education?

Establishing primary questions to achieve the research objectives will yield new insights and knowledge in developing Artificial Intelligence (AI) in vocational education. By answering these questions, this research will provide a comprehensive understanding of how AI can be effectively applied in vocational settings, identify potential challenges, and propose innovative solutions to overcome these barriers. Consequently, the findings will enhance the quality of vocational education and ensure that AI technologies are utilized appropriately and optimally, thereby supporting sustainability and inclusiveness in education.

2. Methodology

This study conducts a comprehensive bibliometric analysis to explore trends, citations, top ten authors, keyword analysis, challenges, and opportunities in the application of artificial intelligence (AI) to vocational education, focusing on research publications from 2014 to 2023. The analysis aims to identify key research patterns, emerging topics, and significant contributions from various researchers and institutions. Additionally, the study examines how AI enhances inclusion, accessibility, and the quality of vocational education, while also assessing its role in supporting the 2030 Sustainable Development Goals (SDGs), particularly in improving education quality, fostering economic growth, and driving industrial innovation.

Using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology, relevant publications are identified, data is analyzed, and findings are systematically presented (Page et al., 2021). This includes an initial screening of the Scopus database to assess publication relevance, quality, and trends over the study period. The analysis evaluates emerging topics, such as AI in vocational education, and maps critical contributions from leading researchers. Furthermore, it assesses how these findings contribute to the 2030 SDGs and considers the challenges and opportunities that influence the outcomes of this research. A flowchart visualizing the data collection and analysis process is presented in Fig. 1.

Fig. 1 presents a PRISMA flow diagram that illustrates the systematic review process employed in the bibliometric analysis of studies related to artificial intelligence (AI) in vocational education. This process consists of four main stages: Identification, Screening, Eligibility, and Inclusion. During the Identification stage, 330 AI-related documents were retrieved from the Scopus database. In the subsequent Screening stage, 304 documents were filtered based on specific criteria, such as document type (articles and conference papers) and language (English), resulting in the exclusion of 26 documents that did not meet the screening requirements.

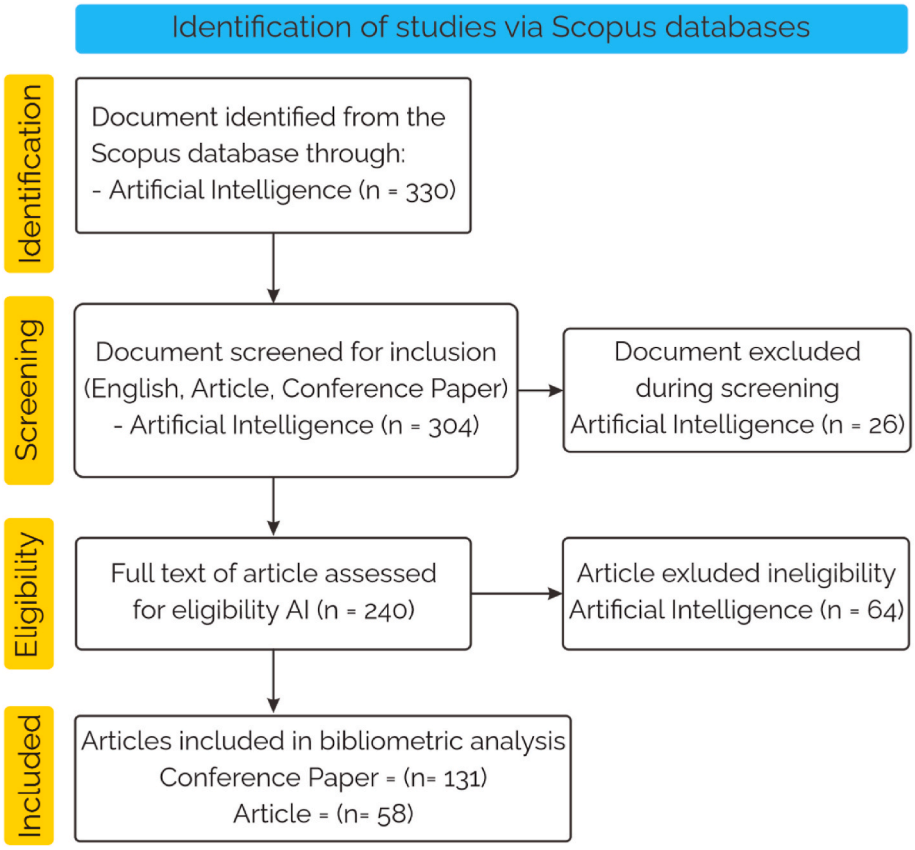

Fig. 1. PRISMA flowchart.

In the Eligibility stage, the full texts of 240 articles were assessed for relevance, and 64 articles were excluded for not sufficiently focusing on the application of AI in vocational education. Finally, in the Inclusion stage, 189 articles—comprising 131 conference papers and 68 articles—were deemed relevant and included in the bibliometric analysis. These articles formed the foundation for analyzing trends, contributions, and emerging topics in the field. The flow diagram highlights the methodological rigor and systematic approach adopted to ensure the inclusion of only relevant and high-quality studies, in line with the PRISMA guidelines used in this research.

In the data collection process, the researchers applied both inclusion and exclusion criteria to narrow the selection of relevant publications are depicted in Table 1. The inclusion criteria focused on publications related to the application of artificial intelligence (AI) in vocational education, published between 2014 and 2023, and available in the Scopus database. Conversely, the exclusion criteria excluded publications unrelated to the research topic, articles that were not available in full text, and those not written in English (Nussbaumer-Streit et al., 2020).

Table 1
Details of the bibliometric data collection process.

Data Sources and Search Strategy (Database of Scopus)	
Database	Scopus
Search Period	2014–2023
Keywords	"Artificial Intelligence," "Vocational Training," "Vocational Education," "AI," "Machine Learning," "Technical Education," "Skills Development"
Keyword Combination	(TITLE-ABS-KEY (artificial AND intelligence) AND TITLE-ABS-KEY (vocational AND education)) AND PUBYEAR >2014 AND PUBYEAR <2023 AND (LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ar")) AND (LIMIT-TO (LANGUAGE, "English")) AND (LIMIT-TO (PUBSTAGE, "final")) AND (LIMIT-TO (SRCTYPE, "j") OR LIMIT-TO (SRCTYPE, "p"))

Data retrieval date: June 17th, 2024.

After establishing publication trends based on the inclusion and exclusion criteria, the next important step is to plan the data analysis techniques to be used. In this bibliometric study, we used descriptive analysis with the help of VOSviewer software to visualize the data distribution. VOSviewer can build a network map of the most influential keywords, authors, and institutions in the literature on artificial intelligence (AI) in vocational education (Prasetya, Fortuna, Samala, et al., 2024). Moreover, by using MS Excel software to summarise quantitative data from the Scopus database. (Majid et al., 2024). The software helped us visualize publication trends in graphs and tables, which supported further analysis of patterns and changes in the investigated literature.

This study concludes by discussing the benefits of integrating AI in vocational education, its contributions toward the SDGs, and the challenges and opportunities in this field. It highlights the potential of AI in advancing sustainable development through enhanced vocational education.

3. Results and discussion

This study delves into the evolving research trends concerning artificial intelligence (AI) within vocational training over the past decade (2014–2023), aiming to uncover prominent emerging topics in academic discourse. Employing a bibliometric analysis, the research aggregated data from multiple sources, including Scopus, to map the progression and shifting patterns of AI integration in vocational education.

3.1. Publication distribution and number of citations each year

The findings of this study underline some of the prominent trends

and topics in Artificial Intelligence (AI) for vocational training in the past decade. AI significantly transforms vocational education by introducing personalized learning experiences tailored to each student's needs and learning style (Jalinus et al., 2023; Le et al., 2022; Putra et al., 2024). This adaptation is facilitated through an AI-based adaptive learning system that analyses student data to optimize the delivery of educational content (Criollo-C et al., 2024; Nurhikmah et al., 2024; Varadila et al., 2023). AI-powered data analytics have enabled institutions to develop curricula responsive to industry demand, predict future skills needs, and identify areas for improvement.

Additionally, AI-driven automation and robotics have reshaped vocational training in sectors such as manufacturing and logistics, offering hands-on experience with advanced technologies (George, 2023). The ethical implications of AI in vocational training, such as privacy concerns and algorithmic bias, also emerged as important considerations. Overall, the influence of AI in vocational training underscores its role in fostering innovative, inclusive, and sustainable learning environments aligned with global education goals and industry needs (Ally & Perris, 2022; Opesemowo & Adekomaya, 2024).

Table 2 presents data on the distribution of the two types of publications in the Artificial Intelligence in Vocational Education domain, including the frequencies and citations received. The recorded data shows that "Conference Papers" appeared 131 times with a total of 258 citations, resulting in an average of 1.97 citations per paper. On the other hand, despite appearing fewer times, "Articles" recorded 58 appearances with a total of 485 citations, resulting in an average of 8.36 citations per article.

The visualization in Fig. 2 supports this distribution of publication trends. In total, 189 publications were counted, with 743 citations, resulting in an average of 10.33 per publication. Analysis of this data concludes that while articles have a lower publication frequency than conference papers, articles tend to receive more citations per publication. This suggests that articles have a more significant impact or value within the scientific community in the context of Artificial Intelligence.

The line chart in Fig. 3 shows two different datasets of the number of publications and the number of citations per year in the Artificial Intelligence domain from 2014 to 2023. In this diagram, the x-axis represents the year, while the y-axis indicates the number ranging from 0 to 180. Further visualization details can be seen in Fig. 3.

In Fig. 3, the blue line, labelled "Distribution of AI Publications," shows an increase each year, suggesting that researchers' interest in this type of AI research has an impact on helping vocational education, peaking in 2021 and 2022 with 45 publications published. The red line, labelled "Citations per Year," also shows variability, with a peak of 163 in 2018 and a drop to 38 in 2023. Both lines have markers at each data point, connected by straight segments, creating a zigzag pattern across the graph. This figure is fascinating because it visually represents trends in publications and citations in artificial intelligence, which can be relevant for understanding the impact of research and interest in this area.

3.2. Top ten most cited author

Table 3 illustraste the ten most frequently cited documents in the field of artificial intelligence (AI) for vocational education over the past decade. These documents come from different regions, with the majority from Asia and one from Europe. Research from the United Kingdom (Avis, 2018) published in the "Journal of Vocational Education and Training" took the top spot with 85 citations, showing the significant influence of Artificial Intelligence on Vocational Education.

In the second place, research from India by Kumar et al. (2023) published in "Applied Sciences (Switzerland)" received 17 citations, followed by research results from Jiang (2022) from the Philippines, who published his article in the Journal "Educational Administration: Theory and Practice" with 13 citations. Meanwhile, the research results of researchers from Taiwan by C. H. Chen et al. (2023) and from China throught B. Chen et al. (2022) each received 11 citations, published in "The Journal of Research on Technology in Education" and "Frontiers in Psychology."

Furthermore, Indonesia study by Dewanto et al. (2018) published in the "Journal of Physics: Conference Series" also received 11 citations, the same as the publications from Taiwan and China. Another research from China by Wu (2021) and Sudira (2019) from Indonesia, which was also published in the "Journal of Physics: Conference Series," received nine citations each. Research by Ni and Wang (2022) from China that was published in "Computational and Mathematical Methods in Medicine" received eight citations, and research by Hou (2021) from China in "The Journal of Physics: Conference Series" received seven citations.

In summary, Table 3 shows that research in artificial intelligence (AI) for vocational education over the past decade has been dominated by publications from Asia, with significant contributions from China and Indonesia. The most frequently cited documents are from the United Kingdom, indicating a global influence, but the majority are from Asia, suggesting a centre of gravity for research in this region. Research from journals tends to have higher citations than conference papers, underlining the importance of journal articles in spreading knowledge and impact in the field of AI for vocational education.

Table 2
Types of publications with citation count data on Artificial Intelligence.

Data retrieval date	Search Period	Publication Type	Frequency	Number of Citations	Average
June 17th, 2024	2014–2023 (Database Scopus)	Conference Paper	131	258	1.97
		Article	58	485	8.36
Total			189	743	10.33

3.3. Themes from the main keywords in the academic literature

Fig. 4 on the network visualization using the software VOSviewer visualization map illustrates a complex landscape of keywords interwoven within the academic literature on Artificial Intelligence (AI) in vocational education. At the heart of this network is the central node, "artificial intelligence," signifying its pivotal role in this field of study. Surrounding it are clusters of interconnected nodes representing key themes such as "vocational education," "e-learning," "higher education," and "teaching methods," which are closely linked to AI's application in educational settings. Other significant nodes include "machine learning," "data mining," and "deep learning," reflecting advanced AI techniques influencing vocational education research. The map also highlights practical aspects like "decision making" and "data handling," indicating AI's role in enhancing educational administration and analysis. The visualization underscores the multidisciplinary nature of AI in vocational education, with nodes like "human," "automation," and "Internet of things" suggesting a convergence of technology, pedagogy, and industry needs. This graphical representation serves as a testament to the growing integration of AI within vocational education, pointing to a future where technology-driven teaching methods are paramount (Fortuna, Prasetya, Luis, et al., 2024; Strielkowski et al., 2024).

Fig. 5, using the software VOSviewer map, illustrates a network of keyword clusters from academic literature on Artificial Intelligence (AI) in vocational education. The terms "artificial intelligence" and "vocational education" are central to this network, indicating a strong focus on integrating AI into vocational learning environments (Larsen et al., 2022).

Surrounding these pivotal terms are clusters that reveal central themes such as "higher education," "vocational colleges," and "teaching methods," suggesting a broad investigation into educational structures and pedagogical approaches (Na, 2024). Presencing of "e-learning" highlights the growing importance of digital platforms in vocational

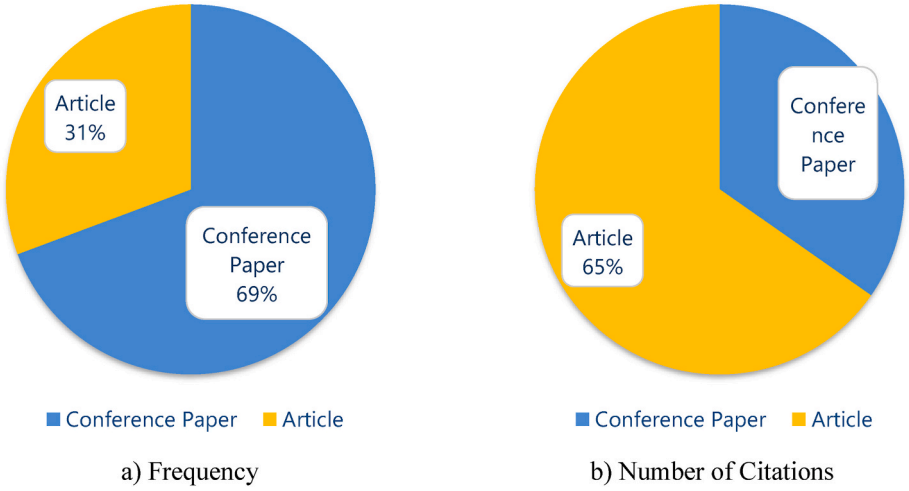

Fig. 2. Percentage distribution of publication trends by artificial intelligence domain in conference papers and articles.

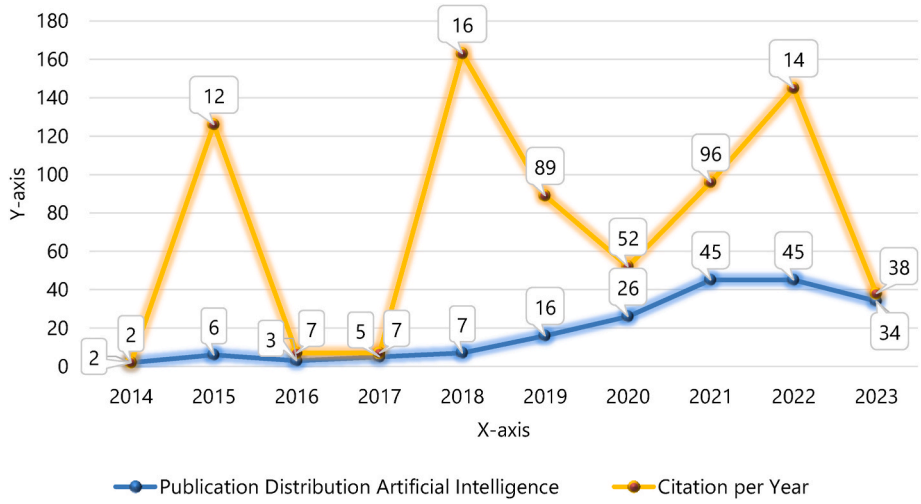

Fig. 3. Average distribution of publications and citations number of all documents in each year.

training. Other significant keywords include “machine learning,” “information technology,” and “deep learning,” pointing to specific AI technologies being explored within the educational context. The map also shows an interest in “data mining,” “information management,” and “decision support systems,” reflecting the data-driven aspect of AI applications. The varying colours, from green to blue, represent different time slices, indicating an evolution in research focus over time. This visual analysis underscores the dynamic nature of AI research in vocational education, mapping out the progression and interconnectivity of crucial concepts over time (Abulibdeh et al., 2024; Yu et al., 2024).

The variation within each cluster presented in Figs. 4 and 5 highlights distinct periods and demonstrates an evolution in research focus over the past decade. This visual representation underscores the multidisciplinary nature of AI in vocational education, bridging technology, pedagogy, and industry needs, in alignment with the findings of (Adel, 2024; U. Yadav & Shrawankar, 2025). Overall, the VOSviewer map provides a comprehensive overview of key themes and clusters in AI research within vocational education, illustrating a dynamic field poised for further innovation and integration into educational practices.

3.4. *Artificial intelligence contributes to sustainable development goals 2030*

Artificial Intelligence (AI) plays a transformative role in advancing the Sustainable Development Goals (SDGs) 2030 by introducing innovative solutions across various sectors (Mhlanga, 2023). Studies demonstrate AI’s potential to significantly contribute to achieving multiple SDGs, particularly in education and workforce development. For instance, AI supports quality education (SDG 4) by enabling personalized learning experiences, real-time feedback, and tailored educational content that ensures accessibility and meets diverse student needs (Ramos et al., 2023). In decent work and economic growth (SDG 8), AI enhances productivity by automating repetitive tasks, allowing workers to focus on more complex activities, and identifying skill gaps to provide targeted training (Morandin et al., 2023). Additionally, AI supports industry, innovation, and infrastructure (SDG 9) by optimizing infrastructure development, driving advanced research, and facilitating the creation of smart cities to foster sustainable urban environments (Mahanta & Lele, 2022).

Beyond these contributions, AI-driven platforms promote lifelong learning and upskilling, critical for adapting to rapidly evolving job markets. Moreover, AI can enhance vocational education by improving access to quality training, optimizing resource allocation, and aligning curricula with industry demands. These innovations improve learning outcomes and ensure that vocational training programs address the needs of underserved communities, fostering inclusive education while supporting sustainable development (Kowsick & Ramasamy, 2024).

Moreover, AI also addresses key challenges across other SDGs. It

Table 3
Top ten most cited documents on artificial intelligence in vocational education.

Author Reference	Region	Journal	Type	Cited by Scopus
J. Avis (Avis, 2018)	United Kingdom	Journal of Vocational Education and Training	Article	85
M. G. V. Kumar et al. (Kumar et al., 2023)	India	Applied Sciences (Switzerland)	Article	17
B. Jiang (Jiang, 2022)	Philippines	Educational Administration: Theory and Practice	Article	13
C. H. Chen et al. (C. H. Chen et al., 2023)	Taiwan	Journal of Research on Technology in Education	Article	11
B. Chen (B. Chen et al., 2022)	China	Frontiers in Psychology	Article	11
W. K. Dewanto et al. (Dewanto et al., 2018)	Indonesia	Journal of Physics: Conference Series	Conference Paper	11
X. Wu (Wu, 2021)	China	Journal of Physics: Conference Series	Conference Paper	9
P. Sudira (Sudira, 2019)	Indonesia	Journal of Physics: Conference Series	Conference Paper	9
Z. Ni and F. Wang (Ni & Wang, 2022)	China	Computational and Mathematical Methods in Medicine	Article	8
Z. Hou (Hou, 2021)	China	Journal of Physics: Conference Series	Conference Paper	7

reduces inequalities (SDG 10) by broadening access to resources and opportunities and mitigating biases in decision-making systems (P. Yadav et al., 2024). In sustainable cities and communities (SDG 11), AI optimizes energy consumption, improves public transportation systems, and strengthens disaster response mechanisms. Furthermore, in combating climate change (SDG 13), AI aids by monitoring environmental data, predicting climate patterns, and developing carbon reduction strategies. It also revolutionizes healthcare (SDG 3) through improved diagnostics, personalized treatment plans, and real-time patient monitoring, particularly benefiting remote and underserved regions.

Additionally, AI enhances water resource management (SDG 6) by improving supply systems and predicting water quality issues. In the energy sector (SDG 7), AI integrates renewable energy, optimizes power distribution, and reduces wastage to make clean energy more affordable and accessible. These capabilities underscore AI's transformative potential in driving sustainable development globally (Awogbemi et al., 2024; Peng et al., 2024).

3.5. Challenges and opportunities

Integrating Artificial Intelligence (AI) into vocational education presents significant challenges and opportunities (Attwell et al., 2020; Johri, 2022; Lérias et al., 2024). Key challenges include limited technological infrastructure in educational institutions, high costs of AI implementation, and a shortage of skilled personnel to manage AI systems effectively (Awaludin et al., 2024; Vrontis et al., 2022). Privacy and ethical concerns also arise due to the extensive data collection and analysis required, necessitating robust governance frameworks to ensure the ethical handling of sensitive information. Additionally, insufficient training for educators on the effective use of AI technologies can hinder their adoption and potential impact in classrooms (Stahl & Wright, 2018).

Despite these challenges, the opportunities are immense. AI can enhance the personalization of learning, providing tailored feedback

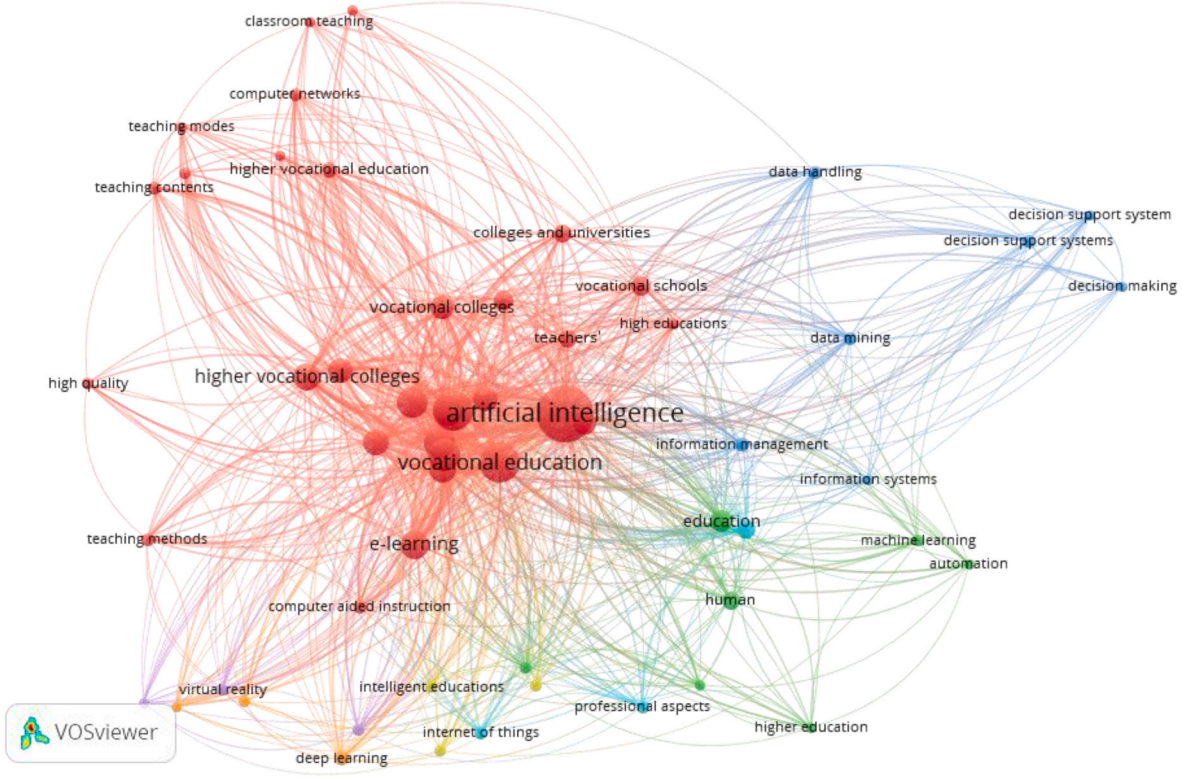

Fig. 4. Network visualization of keywords in Artificial Intelligence for vocational education.

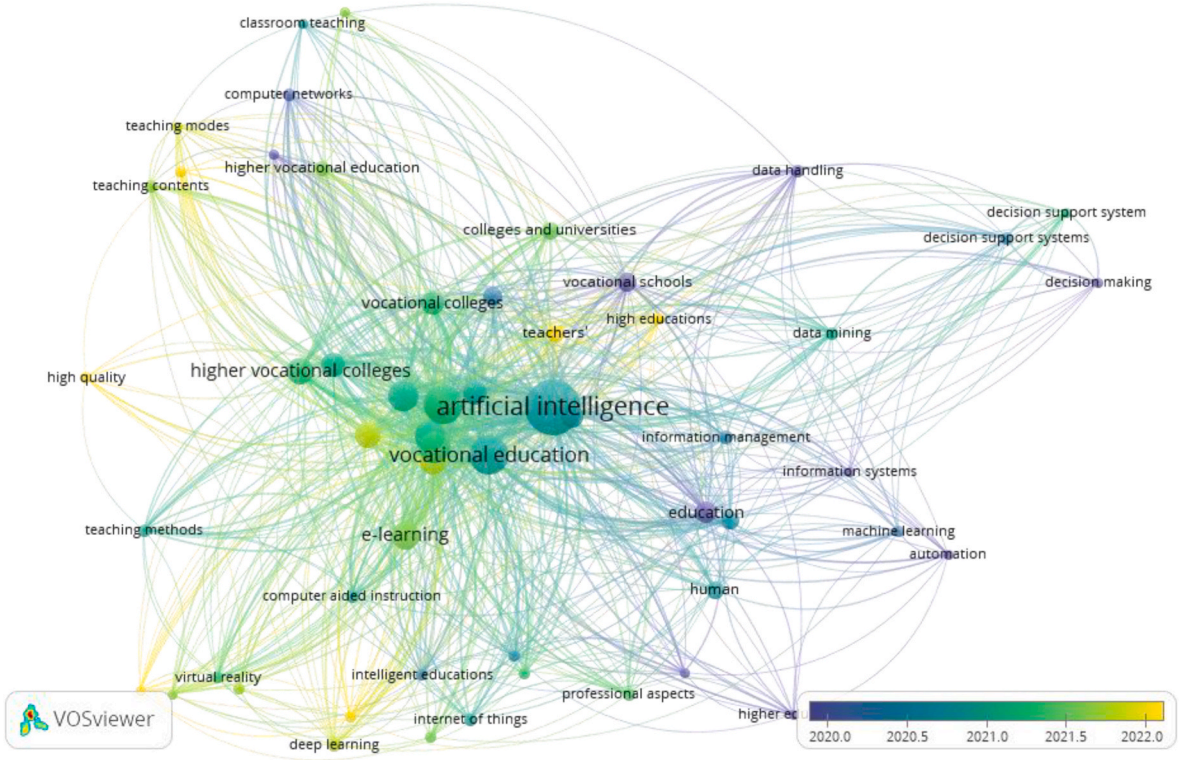

Fig. 5. Overlay visualization of keywords in Artificial Intelligence for vocational education.

and adapting educational content to meet individual learning needs and paces (Sharma et al., 2024). It facilitates project-based learning, is aligned with industry demands, and enables the development of dynamic curricula responsive to evolving labour market requirements. Furthermore, AI-driven tools can simulate real-world environments, providing students with practical, hands-on experiences crucial for their careers (Goel et al., 2024).

Collaborative efforts among governments, educational institutions, and industry stakeholders are essential to address these challenges. For instance, affordable funding models for AI integration, coupled with initiatives to enhance the skills of educators, can mitigate financial and expertise-related barriers (Southworth et al., 2023; Yuwono et al., 2024). Ethical considerations should also be prioritized through comprehensive training programs and stringent data governance policies. These measures will not only ensure responsible AI implementation but also maximize its potential to improve educational outcomes, align vocational training with industry demands, and enhance graduates' job readiness in a competitive global market (Abulibdeh et al., 2024; Chiu et al., 2023; Jafari & Keykha, 2024).

While adopting AI in vocational education comes with hurdles, the substantial benefits of improved learning outcomes, inclusivity, and better alignment with industry needs make it a transformative solution for sustainable development and future workforce demands.

3.6. Implication, limitations, and future prospects

This study underscores the transformative impact of integrating artificial intelligence (AI) technology into vocational education, particularly in personalizing learning experiences and aligning curricula with industry demands. The findings highlight critical implications, including AI's role in fostering inclusive learning environments and advancing vocational education aligned with sustainable development goals, precisely quality education (SDG 4), industry, innovation, and infrastructure (SDG 9). Moreover, the bibliometric analysis reveals that scholarly articles exert a more substantial influence, as evidenced by their higher citation frequency than conference papers. This observation underscores the need for increased publication in leading academic journals to enhance the dissemination and impact of scientific knowledge.

However, the study identifies several limitations requiring further consideration. First, the exclusive reliance on bibliometric data from a single source, Scopus, limits the representation of the broader literature landscape. Future research should integrate multiple databases such as PubMed, Web of Science, and EBSCO to ensure comprehensive coverage. Second, the analysis primarily emphasizes publication and citation quantities, with limited exploration of the quality and real-world impact of the studies reviewed. Lastly, the approach adopted may not adequately capture the current and rapidly evolving trends in AI research within vocational education.

Despite these limitations, this study provides valuable groundwork for future investigations into AI applications to address specific vocational education challenges, such as developing regionally tailored skills and leveraging emerging technologies like MetaHuman, Metaverse, Internet of Things (IoT), and Blockchain. Expanding future research to include diverse databases and advanced analytical methodologies would offer a more holistic understanding of recent trends. Additionally, considering the growing influence of AI in education, future studies should delve into ethical and regulatory dimensions to promote the responsible and inclusive integration of AI technologies in vocational education systems.

4. Conclusion

Over the past decade (2014–2023), this study has explored trends, citation patterns, leading authors, keyword analysis, challenges, opportunities, and the transformative potential of Artificial Intelligence (AI) in vocational education. Through bibliometric analysis, the study reveals that AI plays a pivotal role in expanding access to quality education, improving workforce readiness, and fostering lifelong learning. Notably, AI has transformed vocational education by enabling personalized learning experiences and industry-responsive curricula.

Furthermore, AI-driven technologies such as automation and robotics have revolutionized vocational training in fields like manufacturing and logistics, despite ethical challenges such as data privacy and algorithmic bias that require further attention. For instance, AI-powered data analysis can continuously update curricula to align education with evolving industry needs.

The findings of this study reveal that over the past decade, artificial intelligence (AI) research for vocational education has been predominantly driven by publications from Asia, particularly from China and Indonesia, highlighting the region's pivotal role in advancing this field. While journal articles have a lower publication frequency compared to conference papers, they tend to receive more citations, demonstrating their greater impact within the academic community and emphasizing their essential role in disseminating impactful knowledge. Keyword analysis further identifies "artificial intelligence" as a central theme, with related topics such as "vocational education" and "teaching methods" reflecting AI's transformative influence in educational settings. These trends underscore the growing importance of AI in vocational education, its potential to shape the future of workforce development, and its critical role in advancing the Sustainable Development Goals (SDGs) for 2030, particularly in promoting quality education and fostering economic growth.

Additionally, the integration of AI in vocational education is closely linked to SDGs 2030, particularly Goal 4 (Quality Education), Goal 8 (Decent Work and Economic Growth), and Goal 9 (Industry, Innovation, and Infrastructure), as discussed in recent studies (Mhlanga, 2023; Vinuesa et al., 2020). For example, AI can provide equitable educational opportunities, reducing disparities in education (Opesemowo & Adekomaya, 2024), while also stimulating economic growth by creating jobs and enhancing employability in the labor market. However, challenges such as ethical concerns, insufficient technological infrastructure, data privacy, and educators' limited understanding of AI technologies must be addressed to fully harness AI's potential in vocational education (Dwivedi et al., 2021; Stahl & Wright, 2018). These findings underscore the need for multidisciplinary efforts to advance AI's integration into vocational education systems, ensuring that its transformative benefits are realized while mitigating associated risks.

Declaration of the use of AI-assisted technologies

During the preparation of this work, the authors used Grammarly to enhance the readability and clarity of the article. Grammarly was employed solely for language refinement, including grammar and style improvements. After utilizing this tool, the authors carefully reviewed and edited the content as needed and took full responsibility for the final version of the publication.

Data availability

All data associated with this systematic review can be obtained from the corresponding author upon reasonable request.

Funding statement

Not applicable.

Ethics statement

This study is based on a bibliometric analysis of publicly available literature and does not involve human participants, personal data collection, or animal research. Therefore, ethical approval was not required. The authors have ensured that all sources are properly cited and have adhered to ethical research and publication practices.

CRediT authorship contribution statement

Febri Prasetya: Writing – review & editing, Writing – original draft, Visualization, Funding acquisition, Formal analysis, Data curation, Conceptualization. **Aprilla Fortuna:** Writing – review & editing, Writing – original draft, Visualization, Software, Resources, Conceptualization. **Agariadne Dwinggo Samala:** Writing – review & editing, Visualization, Supervision, Resources, Methodology, Formal analysis. **Dinda Khaira Latifa:** Writing – review & editing, Visualization, Formal analysis, Data curation. **Welli Andriani:** Writing – review & editing, Visualization, Software, Project administration, Methodology. **Utari Akhir Gusti:** Writing – review & editing, Investigation, Data curation. **Muhammad Raihan:** Writing – review & editing, Software, Resources, Formal analysis. **Santiago Criollo-C:** Writing – review & editing, Visualization, Validation, Methodology. **Deniz Kaya:** Writing – review & editing, Validation, Project administration, Investigation. **Juan Luis Cabanillas García:** Writing – review & editing, Validation, Supervision, Resources, Conceptualization.

Declaration of competing interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

This declaration is made to ensure transparency and maintain the integrity of the review and publication process. If there are other authors, they declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

Abulibdeh, A., Zaidan, E., & Abulibdeh, R. (2024). Navigating the confluence of artificial intelligence and education for sustainable development in the era of industry 4.0: Challenges, opportunities, and ethical dimensions. *Journal of Cleaner Production, 437*, Article 140527. https://doi.org/10.1016/j.jclepro.2023.140527

Adel, A. (2024). The convergence of intelligent tutoring, robotics, and IoT in smart education for the transition from industry 4.0 to 5.0. *Smart Cities, 7*(1), 325–369. https://doi.org/10.3390/smartcities7010014

Ally, M., & Perris, K. (2022). Artificial intelligence in the fourth industrial revolution to educate for sustainable development. *Canadian Journal of Learning and Technology, 48*(4), 1–20. https://doi.org/10.21432/cjlt28287

Attwell, G., Bekiaridis, G., Deitmer, L., Perini, M., Roppertz, S., & Tutlys, V. (2020). Artificial intelligence in policies, processes and practices of vocational education and training. In *Institut Technik und Bildung* (Vol. 71). Universität Bremen. https://doi.org/10.26092/elib/307

Avis, J. (2018). Socio-technical imaginary of the fourth industrial revolution and its implications for vocational education and training: A literature review. *Journal of Vocational Education and Training, 70*(3), 337–363. https://doi.org/10.1080/13636820.2018.1498907

Awaludin, M., Yasin, V., & Risyda, F. (2024). The influence of artificial intelligence technology, infrastructure and human resource competence on Internet access networks. *Inform: Jurnal Ilmiah Bidang Teknologi Informasi Dan Komunikasi, 9*(2), 111–120. https://doi.org/10.25139/inform.v9i2.8109

Awogbemi, O., Von Kallon, D. V., & Kumar, K. S. (2024). Contributions of artificial intelligence and digitization in achieving clean and affordable energy. *Intelligent Systems with Applications, 22*, Article 200389. https://doi.org/10.1016/j.iswa.2024.200389

Bhutoria, A. (2022). Personalized education and artificial intelligence in the United States, China, and India: A systematic review using a human-in-the-loop model. *Computers and Education: Artificial Intelligence, 3*, Article 100068. https://doi.org/10.1016/j.caeai.2022.100068

Chen, C. H., Liu, T. K., & Huang, K. (2023). Scaffolding vocational high school students' computational thinking with cognitive and metacognitive prompts in learning about programmable logic controllers. *Journal of Research on Technology in Education, 55*(3), 527–544. https://doi.org/10.1080/15391523.2021.1983894

Chen, B., Liu, Y., & Zheng, J. (2022). Using data mining approach for student satisfaction with teaching quality in high vocation education. *Frontiers in Psychology, 12*, 1–9. https://doi.org/10.3389/fpsyg.2021.746558

Chiu, T. K. F., Xia, Q., Zhou, X., Chai, C. S., & Cheng, M. (2023). Systematic literature review on opportunities, challenges, and future research recommendations of artificial intelligence in education. *Computers and Education: Artificial Intelligence, 4*, Article 100118. https://doi.org/10.1016/j.caeai.2022.100118

Criollo-C, S., Guerrero-Arias, A., Cerezo, J. E., Arif, Y. M., Fortuna, A., Prasetya, F., et al. (2024). Improving higher education with the use of mobile augmented reality (mar): A case study. *IEEE Access, 12*(October), 139003–139017. https://doi.org/10.1109/ACCESS.2024.3465833

Dewanto, W. K., Agustianto, K., & Sari, B. E. (2018). Developing thinking skill system for modelling creative thinking and critical thinking of vocational high school student. *Journal of Physics: Conference Series, 953*(1), 1–6. https://doi.org/10.1088/1742-6596/953/1/012115

Dwivedi, Y. K., Hughes, L., Ismagilova, E., Aarts, G., Coombs, C., Crick, T., et al. (2021). Artificial Intelligence (AI): Multidisciplinary perspectives on emerging challenges, opportunities, and agenda for research, practice and policy. *International Journal of Information Management, 57*, Article 101994. https://doi.org/10.1016/j.ijinfomgt.2019.08.002

Fortuna, A., Prasetya, F., Luis, J., García, C., Maria, J., Salman, A., et al. (2024a). Modern learning paradigms : A bibliometric analysis of augmented reality and virtual reality in vocational education. *Jurnal Pendidikan Teknologi Kejuruan, 7*(2), 91–114. https://doi.org/10.24036/jptk.v7i2.36523

Fortuna, A., Prasetya, F., Samala, A. D., Andriani, W., Rawas, S. S. A. R., Chai, H., et al. (2024b). Enhancing occupational health and safety education: A mobile gamification approach in machining workshops. *International Journal of Information and Education Technology, 14*(9), 1227–1238. https://doi.org/10.18178/ijiet.2024.14.9.2152

Garlinska, M., Osial, M., Proniewska, K., & Pregowska, A. (2023). The influence of emerging technologies on distance education. *Electronics (Switzerland), 12*(7), 1–29. https://doi.org/10.3390/electronics12071550

George, A. S. (2023). Preparing students for an AI-driven world: Rethinking curriculum and pedagogy in the age of artificial intelligence. *Partners Universal Innovative Research Publication (PUIRP), 1*(2), 112–136. https://doi.org/10.5281/zenodo.10245675

Goel, P. K., Singhal, A., Bhadoria, S. S., Saraswat, B. K., & Patel, A. (2024). AI and machine learning in smart education: Enhancing learning experiences through intelligent technologies. In *Infrastructure possibilities and human-centered approaches with industry 5.0* (pp. 1–20). https://doi.org/10.4018/979-8-3693-0782-3.ch003

Hou, Z. (2021). Research on adopting artificial intelligence technology to improve effectiveness of vocational college English learning. *Journal of Physics: Conference Series, 1744*(4), 1–7. https://doi.org/10.1088/1742-6596/1744/4/042122

Jafari, F., & Keykha, A. (2024). Identifying the opportunities and challenges of artificial intelligence in higher education: A qualitative study. *Journal of Applied Research in Higher Education, 16*(4), 1228–1245. https://doi.org/10.1108/JARHE-09-2023-0426

Jalinus, N., Haq, S., & Kassymova, G. K. (2023). Work-based learning for the engineering field in vocational education : Understanding concepts , principles and best practices. *Journal of Engineering Researcher and Lecturer, 2*(1), 9–17. https://doi.org/10.58712/jerel.v2i1.22

Javaid, M., Haleem, A., & Suman, R. (2023). Digital twin applications toward industry 4.0: A review. *Cognitive Robotics, 3*, 71–92. https://doi.org/10.1016/j.cogr.2023.04.003

Jiang, B. (2022). Study on the application of Chinese traditional culture teaching in higher vocational education. *Educational Administration: Theory and Practice, 28*(3), 142–155. https://doi.org/10.17762/kuey.v28i03.486

Johri, A. (2022). Augmented sociomateriality: Implications of artificial intelligence for the field of learning technology. *Research in Learning Technology, 30*(1063519), 1–13. https://doi.org/10.25304/rlt.v30.2642

Kowsick, N. P., & Ramasamy, K. (2024). Implementing AI-based recommendation systems for personalized financial services in libraries. In *Improving library systems with AI: Applications, approaches, and bibliometric insights* (pp. 1–9). https://doi.org/10.4018/979-8-3693-5593-0.ch017

Kumar, M. G. V., Veena, N., Čepová, L., Raja, M. A. M., Balaram, A., & Elangovan, M. (2023). Evaluation of the quality of practical teaching of agricultural higher vocational courses based on BP neural network. *Applied Sciences, 13*(2), 1–10. https://doi.org/10.3390/app13021180

Larsen, C., Kipper, J., Schmid, A., & Ricceri, M. (2022). The relevance of artificial intelligence in the digital and green transformation of regional and local labour markets across europe. *Perspectives on Employment, Training, Placement, and Social Inclusion*. https://doi.org/10.5771/9783957104113

Le, S. K., Hlaing, S. N., & Ya, K. Z. (2022). 21st-century competences and learning that Technical and vocational training. *Journal of Engineering Researcher and Lecturer, 1*(1), 1–6. https://doi.org/10.58712/jerel.v1i1.4

Lérias, E., Guerra, C., & Ferreira, P. (2024). Literacy in artificial intelligence as a challenge for teaching in higher education: A case study at portalegre polytechnic university. *Information, 15*(4), 1–14. https://doi.org/10.3390/info15040205

Mahanta, N. R., & Lele, S. (2022). Evolving trends of artificial intelligence and robotics in smart city applications: Crafting humane built environment. In *Trust-based communication systems for Internet of things applications* (pp. 195–241). John Wiley & Sons, Ltd. https://doi.org/10.1002/9781119896746.CH9.

Majid, M. Z. A., Kasavan, S., & Siron, R. (2024). Bibliometric analysis and science mapping of global scientific publications on technical vocational education training (TVET). *Library Hi Tech, 42*(1), 8–32. https://doi.org/10.1108/LHT-12-2021-0485

Mhlanga, D. (2023). FinTech and artificial intelligence for sustainable development: The role of smart technologies in achieving development goals. In *FinTech and artificial intelligence for sustainable development* (pp. 3–13). Cham: Palgrave Macmillan. https://doi.org/10.1007/978-3-031-37776-1_1.

Morandin, S., Fraboni, F., Angelis, M. De, Puzzo, G., Giusino, D., & Pietrantoni, L. (2023). The impact of artificial intelligence on workers' skills: Upskilling and reskilling in organisations. *Informing Science: The International Journal of an Emerging Transdiscipline, 26*, 1–30. https://doi.org/10.28945/5078

Muskhir, M., Luthfi, A., Watrianthos, R., Usmeldi, U., Fortuna, A., & Samala, A. D. (2024). Emerging research on virtual reality applications in vocational education: A bibliometric analysis. *Journal of Information Technology Education: Innovations in Practice, 23*, 1–26. https://doi.org/10.28945/5284

Na, H. (2024). Visualization of research hotspots and evolutionary pathways in Chinese undergraduate vocational education from the perspective of biological Sciences. *Journal of Commercial Biotechnology, 29*(2), 142–153. https://doi.org/10.5912/jcb1920

Ni, Z., & Wang, F. (2022). Quality assessment of vocational education teaching reform based on deep learning. *Computational and Mathematical Methods in Medicine, 1–11*. https://doi.org/10.1155/2022/1499420

Nurhikmah, Ropianto, M., & Adi, N. H. (2024). Intelligent system for college selection with analytical hierarchy process method case study approach. *Journal of Computer-Based Instructional Media, 2*(1), 42–52. https://doi.org/10.58712/jcim.v2i1.130

Nussbaumer-Streit, B., Klerings, I., Dobrescu, A. I., Persad, E., Stevens, A., Garritty, C., et al. (2020). Excluding non-English publications from evidence-syntheses did not change conclusions: A meta-epidemiological study. *Journal of Clinical Epidemiology, 118*, 42–54. https://doi.org/10.1016/j.jclinepi.2019.10.011

Odo, M. I. (2023). Managerial techniques required of principals of technical and vocational colleges for quality assurance and skill acquisition. *Jurnal Pendidikan Teknologi Kejuruan, 6*(1), 9–17. https://doi.org/10.24036/jptk.v6i1.28523

Ojeaga, I. J., & Dumbiri, D. N. (2023). Perceptions of strategies for revitalizing industrial work experience scheme toward vocational and business education graduates' employability in public universities, Nigeria. *Jurnal Pendidikan Teknologi Kejuruan, 6*(4), 256–269. https://doi.org/10.24036/jptk.v6i4.34123

Opesemowo, O. A. G., & Adekomaya, V. (2024). Harnessing artificial intelligence for advancing sustainable development goals in South Africa's higher education system: A qualitative study. *International Journal of Learning, Teaching and Educational Research, 23*(3), 67–86. https://doi.org/10.26803/ijlter.23.3.4

Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., et al. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *The BMJ, 372*, 1–9. https://doi.org/10.1136/bmj.n71

Peng, X., Guan, X., Zeng, Y., & Zhang, J. (2024). Artificial intelligence-driven multi-energy optimization: Promoting green transition of rural energy planning and sustainable energy economy. *Sustainability, 16*(10), 4111. https://doi.org/10.3390/su16104111

Prasetya, F., Fortuna, A., Jalinus, N., Refdinal, R., Fajri, R., Wulansari, R. E., et al. (2024a). Revolutionizing CNC lathe education: Designing instructional media integrated using augmented reality technology. *TEM Journal, 13*(2), 1695–1701. https://doi.org/10.18421/TEM132-82

Prasetya, F., Fortuna, A., Samala, A. D., Fajri, B. R., Efendi, F., & Nyamapfene, A. (2023). Effectiveness of distance learning computer numerical control based on virtual laboratory using a Metaverse platform to improve students' cognitive ability and practice skills. *International Journal of Interactive Mobile Technologies (IJIM), 17*(24), 4–21. https://doi.org/10.3991/ijim.v17i24.45019

Prasetya, F., Fortuna, A., Samala, A. D., Rawas, S., Mystakidis, S., Syahril, S., et al. (2024b). The impact of augmented reality learning experiences based on the motivational design model: A meta-analysis. *Social Sciences & Humanities Open, 10* (May), Article 100926. https://doi.org/10.1016/j.ssaho.2024.100926

Putra, R. E., Indrawan, E., & Fortuna, A. (2024). Effect of implementing demonstration method on students' understanding and practical skills in Milling Machining Course. *Journal of Engineering Researcher and Lecturer, 3*(1), 35–45. https://doi.org/10.58712/jerel.v3i1.125

Rahim, B., Ambiyar, A., Waskito, W., Fortuna, A., Prasetya, F., Andriani, C., et al. (2024). Effectiveness of project-based learning in metal welding technology course with STEAM approach in vocational education. *TEM Journal, 13*(2), 1481–1492. https://doi.org/10.18421/TEM132-62

Ramos, L., Rivas-Echeverria, F., Casas, E., & Perez, A. G. (2023). The role of artificial intelligence in enhancing sustainability in the fashion industry: A 2012-2022 review. *International Conference on Mathematics and Computers in Sciences and Industry*, 89–95. https://doi.org/10.1109/MCSI60294.2023.00022

Ran, Q., & Han, D. (2023). Application of artificial intelligence to deep learning in vocational education. *EEE international conference on electrical, automation and computer engineering*. https://doi.org/10.1109/ICEACE60673.2023.10442721

Renz, A., & Hilbig, R. (2021). Correction to: Prerequisites for artificial intelligence in further education: Identification of drivers, barriers, and business models of educational technology companies (international journal of educational technology in higher education, (2020), 17, 1. *International Journal of Educational Technology in Higher Education, 18*(1), 1–21. https://doi.org/10.1186/s41239-021-00245-2

Sandhu, R., Channi, H. K., Ghai, D., Cheema, G. S., & Kaur, M. (2024). An introduction to generative AI tools for education 2030. In *Integrating generative AI in education to achieve sustainable development goals* (pp. 1–28). IGI Global.

Sharma, S. K., Dixit, R. J., Rai, D., & Mall, S. (2024). Artificial intelligence and machine learning in smart education. In *Infrastructure possibilities and human-centered approaches with industry 5.0* (pp. 86–106). IGI Global. https://doi.org/10.4018/979-8-3693-0782-3.CH006.

Shen, Y., Liu, Q., Zhang, K., & Zou, R. (2024). The application of artificial intelligence technology in vocational college training. *Recent trends in educational technology and administration*. https://doi.org/10.1007/978-3-031-60777-6_11

Southworth, J., Migliaccio, K., Glover, J., Glover, J. N., Reed, D., McCarty, C., et al. (2023). Developing a model for AI across the curriculum: Transforming the higher education landscape via innovation in AI literacy. *Computers and Education: Artificial Intelligence, 4*(January), Article 100127. https://doi.org/10.1016/j.caeai.2023.100127

Stahl, B. C., & Wright, D. (2018). Ethics and privacy in AI and big data: Implementing responsible research and innovation. *IEEE Security and Privacy, 16*(3), 26–33. https://doi.org/10.1109/MSP.2018.2701164

Strielkowski, W., Grebennikova, V., Lisovskiy, A., Rakhimova, G., & Vasileva, T. (2024). AI-driven adaptive learning for sustainable educational transformation. *Sustainable Development*, 1–27. https://doi.org/10.1002/sd.3221

Sudira, P. (2019). The role of vocational education in the era of industrial automation. *Journal of Physics: Conference Series, 1273*(1), 1–6. https://doi.org/10.1088/1742-6596/1273/1/012058

Sutikno, S. (2024). Enhancing supervision efficiency and satisfaction: Evaluating the impact of the e-monprakerin model on vocational high school apprenticeship monitoring. *Jurnal Pendidikan Teknologi Kejuruan, 7*(2), 64–75. https://doi.org/10.24036/jptk.v7i2.36023

Varadila, J., Meilisa, R., Imamudin, Annisa, A., & Folkourng, F. (2023). Development of learning media based on macromedia flash 8 to see learning outcomes and achievements in vocational high school students. *Journal of Computer-Based Instructional Media, 1*(1), 9–18. https://doi.org/10.58712/jcim.v1i1.16

Vinuesa, R., Azizpour, H., Leite, I., Balaam, M., Dignum, V., Domisch, S., et al. (2020). The role of artificial intelligence in achieving the Sustainable Development Goals. *Nature Communications, 11*(1), 1–10. https://doi.org/10.1038/s41467-019-14108-y

Vrontis, D., Christofi, M., Pereira, V., Tarba, S., Makrides, A., & Trichina, E. (2022). Artificial intelligence, robotics, advanced technologies and human resource management: A systematic review. *International Journal of Human Resource Management, 33*(6), 1237–1266. https://doi.org/10.1080/09585192.2020.1871398

Wu, X. (2021). Application of artificial intelligence in modern vocational education technology. *Journal of Physics: Conference Series, 1881*(3), 1–6. https://doi.org/10.1088/1742-6596/1881/3/032074

Wulansari, R. E., Fortuna, A., Marta, R., Primawati, P., Masek, A., Kaya, D., et al. (2024). Revolutionizing learning: Unleashing the power of technology gamification-augmented reality in vocational education. *TEM Journal, 13*(3), 2384–2397. https://doi.org/10.18421/TEM133-65

Yadav, U., & Shrawankar, U. (2025). Artificial intelligence across industries: A comprehensive review with a focus on education. *AI Applications and Strategies in Teacher Education, 46*. https://doi.org/10.4018/979-8-3693-5443-8.ch010

Yadav, P., Tudela, L. A. M., & Marco-Lajara, B. (2024). The role of AI in assessing and achieving the sustainable development goals (SDGs). In *Issues of sustainability in AI and new-age thematic investing* (pp. 1–7). https://doi.org/10.4018/979-8-3693-3282-5.ch001

Yu, J. H., Chauhan, D., Iqbal, R. A., & Yeoh, E. (2024). Mapping academic perspectives on AI in education: Trends, challenges, and sentiments in educational research (2018–2024). *Educational Technology Research & Development*. https://doi.org/10.1007/s11423-024-10425-2. *0123456789*.

Yuwono, E. I., Tjondronegoro, D., Riverola, C., & Loy, J. (2024). Co-creation in action: Bridging the knowledge gap in artificial intelligence among innovation champions. *Computers and Education: Artificial Intelligence, 7*(May), Article 100272. https://doi.org/10.1016/j.caeai.2024.100272