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Bibliometric and Systematic Review of AI-Assisted Adaptive Learning Applications in Vocational Education (2018-2023)

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ABSTRACT

The integration of Artificial Intelligence (AI) into adaptive learning systems has gained traction in vocational education due to its potential to personalize instruction and enhance competency-based learning. However, research on this intersection remains fragmented, particularly in the context of vocational education and training (TVET). This study conducts a Systematic Literature Review (SLR) using the PRISMA protocol, combined with bibliometric analysis using VOSviewer, to map research trends on AI-assisted adaptive learning in vocational education from 2018 to 2023. Data were sourced from Scopus, Semantic Scholar, and Google Scholar, resulting in 41 eligible articles. The findings reveal a sharp increase in publications after 2020, reflecting growing interest in AI-driven innovations, particularly during the COVID-19 pandemic. Bibliometric mapping identified three dominant thematic clusters: AI-enabled personalization, competency-based vocational education, and pedagogical innovation. Geographically, most research originates from technologically advanced countries such as the United States, India, and the United Kingdom. The study highlights the strategic role of AI-assisted adaptive learning in supporting individualized pathways and skills alignment in vocational education. It also identifies gaps in longitudinal evaluation, pedagogical integration, and research representation from developing regions. These insights provide practical implications for policymakers, educators, and curriculum developers aiming to modernize vocational training systems through AI.

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1. INTRODUCTION

The rapid advancement of Artificial Intelligence (AI) has fundamentally transformed various sectors, including education, by enabling data-driven, adaptive, and personalized learning environments. In recent years, AI has been increasingly integrated into educational systems to support adaptive learning, allowing instructional content, pacing, and assessment to be dynamically adjusted based on learners' characteristics, performance, and learning behaviors (Khalil et al., 2021; Carolus et al., 2023). Adaptive

learning supported by AI is widely recognized for its potential to enhance learning effectiveness, learner engagement, and instructional efficiency, particularly in technology-enhanced learning contexts.

Within this broader educational transformation, vocational education and training (TVET) occupies a distinctive position. Unlike general or academic education, vocational education emphasizes competency mastery, practical skills, and workforce readiness, requiring learning systems that can accommodate heterogeneous learner profiles and diverse competency trajectories (Choy & Yeung, 2022; Jalinus et al., 2021). Vocational learners often enter programs with varied prior knowledge, learning speeds, and professional goals, making uniform instructional approaches less effective. Consequently, vocational education demands learning models that are flexible, individualized, and responsive to real-time performance data.

AI-assisted adaptive learning offers significant promise in addressing these challenges. By leveraging machine learning algorithms, intelligent tutoring systems, and data analytics, adaptive learning platforms can identify individual competency gaps, recommend personalized learning pathways, and provide timely feedback aligned with industry-oriented competencies (Reigeluth & An, 2020; Christopoulos & Sprangers, 2021). In vocational contexts, this capability is particularly valuable, as it supports personalized competency development, improves alignment between learning outcomes and labor market demands, and reduces skills mismatch—an issue frequently highlighted in vocational education discourse (Muafi et al., 2021).

The urgency for adopting adaptive and intelligent learning approaches in vocational education has intensified following the COVID-19 pandemic, which accelerated digital transformation across educational institutions worldwide. During and after the pandemic, vocational education institutions faced significant challenges in maintaining practical and competency-based learning in online or blended environments (Adnan & Anwar, 2020; Maskar et al., 2020). This situation highlighted the limitations of conventional e-learning systems, which often lack personalization and fail to support individual competency tracking. As a result, AI-assisted adaptive learning has emerged as a strategic solution to enhance learning continuity, personalization, and instructional quality in vocational education.

Despite growing interest in AI and adaptive learning, existing research demonstrates a notable gap when examined specifically from the vocational education perspective. Many studies focus on AI applications in general education, higher education, or technical system development without explicitly addressing the pedagogical, curricular, and competency-based characteristics of vocational education (Gleason, 2018; Castro, 2019). Furthermore, while several studies explore adaptive learning frameworks or intelligent tutoring systems, they often do so in isolated contexts, lacking a comprehensive synthesis of how AI-assisted adaptive learning has been conceptualized, implemented, and evaluated within vocational education systems.

Another critical gap lies in the lack of systematic mapping of research trends in this field. Although bibliometric studies and systematic literature reviews have been conducted on AI in education or adaptive learning separately, studies that integrate bibliometric analysis with PRISMA-based systematic review focusing explicitly on vocational education remain limited. Existing reviews tend to emphasize technological sophistication rather than contextual alignment with vocational education goals, such as competency certification, industry relevance, and skills transferability (Ma & Xu, 2020; Omar et al., 2019). Consequently, stakeholders lack a consolidated overview of dominant research themes, publication trends, and geographical contributions related to AI-assisted adaptive learning in vocational education.

Addressing this gap is essential for advancing both research and practice. A comprehensive understanding of how AI-assisted adaptive learning has evolved within vocational education can inform policy formulation, curriculum design, instructional innovation, and future research directions. Mapping publication trends, thematic clusters, and country contributions can also reveal disparities in research development and highlight opportunities for cross-national collaboration, particularly for developing countries seeking to modernize vocational education systems (Ghufron, 2018; Dyah et al., 2022).

In response to these gaps, this study adopts a Systematic Literature Review (SLR) using the PRISMA protocol, combined with bibliometric analysis using VOSviewer, to provide a structured and

comprehensive overview of AI-assisted adaptive learning research from a vocational education perspective. By integrating these two approaches, the study not only synthesizes research content but also visualizes the intellectual structure and development patterns of the field. This approach enables a more nuanced understanding of how AI, adaptive learning, and vocational education intersect within contemporary educational research. Accordingly, this study is guided by the following research objectives and questions:

1. To identify publication trends related to AI-assisted adaptive learning in vocational education from 2018 to 2023.
2. To examine dominant research themes and keyword clusters emerging in the literature on AI-assisted adaptive learning within vocational education.
3. To analyze the geographical distribution and country contributions in research on AI-assisted adaptive learning in vocational education.

By addressing these objectives, this study aims to contribute theoretically by clarifying the research landscape and empirically by providing evidence-based insights for vocational education policymakers, educators, curriculum developers, and institutional leaders. Ultimately, the study seeks to support the strategic integration of AI-assisted adaptive learning as a transformative approach for enhancing competency-based, personalized, and workforce-oriented vocational education.

2. METHODS

This study employed a Systematic Literature Review (SLR) integrated with bibliometric analysis to comprehensively examine research on AI-assisted adaptive learning in vocational education. The SLR was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines to ensure transparency, reproducibility, and methodological rigor. Bibliometric analysis using VOSviewer was applied to map publication trends, keyword co-occurrence, thematic clusters, and geographical research contributions. This combined approach was selected to not only synthesize existing empirical and conceptual studies but also to visualize the intellectual structure and development patterns of the research field.

2.1 Search Strategy and Data Sources

The literature search was conducted using several academic databases, including Google Scholar, Scopus, and Semantic Scholar. The search employed key terms such as “artificial intelligence,” “adaptive learning,” and “vocational education,” as well as related variations including “AI in vocational training,” “personalized learning with AI,” and “intelligent tutoring systems AND TVET” (Firzatullah, 2021). These keywords were selected to identify relevant studies examining the application of artificial intelligence in supporting adaptive and personalized learning within vocational and technical education contexts.

Search limitations and specification details are shown in Table 1.

Table 1. SLR Publication Specifications

Year	2018-2022
Possible Targets	40-50
Journal Accreditation	Nationally Accredited or Internationally Reputable
Target Keywords	artificial intelligence, adaptive learning, vocational education.

Additional variations included:
“AI in vocational training”

"Intelligent tutoring systems AND TVET"
"personalized learning with AI"
The search covered publications from 2018 to 2023, reflecting recent developments in AI and post-pandemic digital transformation in education.

2.2 SLR Approach Using PRISMA

Data Sources and Database Selection The literature search was conducted using three major academic databases: Scopus, Semantic Scholar, and Google Scholar. These databases were selected to balance quality control, coverage breadth, and interdisciplinary representation.

a. Scopus was chosen due to its strong reputation for indexing high-quality, peer-reviewed journals with rigorous editorial standards, particularly in education, technology, and engineering fields.
b. Semantic Scholar was included to capture emerging and interdisciplinary research that may not yet be fully indexed in traditional databases, especially in AI and educational technology.
c. Google Scholar was used to broaden coverage, particularly for reputable conference proceedings and regionally published journals relevant to vocational education.

The use of multiple databases inevitably introduces coverage overlap and citation variability, especially with Google Scholar, which includes a wider range of sources. To mitigate potential bias, a strict screening and eligibility process was applied, and duplicate records were systematically removed.

2.3 PRISMA Procedure

The article selection in this study follows the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) protocol, which consists of four main stages. The first stage is identification, involving the collection of articles from various databases such as Google Scholar, Scopus, and Semantic Scholar using relevant keyword combinations. In this stage, all articles related to adaptive learning, artificial intelligence, and vocational education were downloaded in bibliographic formats (.ris and .csv) for further analysis. The second stage is screening, which was carried out by removing duplicates and evaluating titles and abstracts to ensure initial relevance to the research focus (Widjanarko et al., 2021). Articles that were thematically or methodologically irrelevant were eliminated from the list. In the next stage, eligibility, a full-text review was conducted to confirm the alignment of each article's content with the context of AI-based adaptive learning in vocational education. The final stage is inclusion, in which a set of articles meeting all criteria were selected for bibliometric and meta-analysis. These included articles serve as the primary sources for extracting information on research trends, keyword distributions, author collaborations, and the effectiveness of AI implementation in adaptive learning within vocational education. The detailed PRISMA process is illustrated in Figure 1 (Callejas et al., 2023).

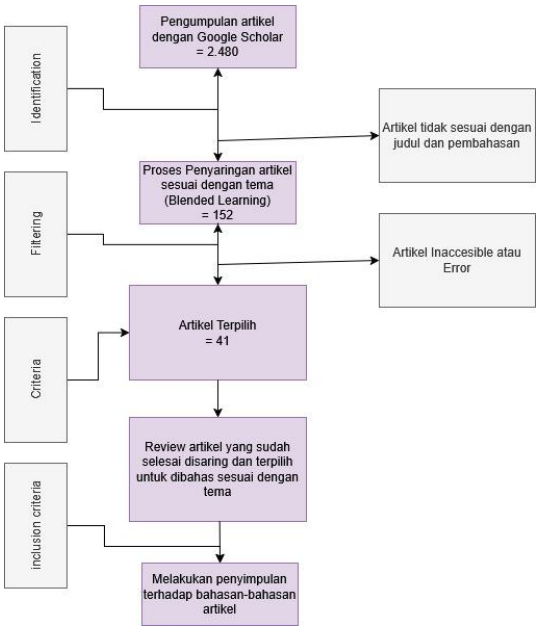

Figure 1. Flowmap PRISMA

2.4 Bibliometric Analysis

Bibliometric analysis in this study was conducted to evaluate the characteristics and trends of scientific publications discussing AI-assisted adaptive learning in the context of vocational education. All articles that passed the inclusion stage were processed using VOSviewer software. Bibliographic data from .ris and .csv files were imported into VOSviewer to generate visualizations of relationships among elements within the literature. Additionally, publication trends by year were analyzed to observe the dynamics of research development over time. The resulting visualizations included network maps and thematic clusters that help reveal the direction of scientific advancement in AI-based adaptive learning, particularly within vocational education. (Omar et al., 2019).

3. FINDINGS AND DISCUSSION

The analysis of references collected since 2018 reveals a gradual increasing publication trend on the topic of artificial intelligence in adaptive learning within the context of vocational education. The graph in Figure 2 illustrates the number of identified articles per year. A significant surge in publications began around 2020, likely driven by the rising demand for adopting adaptive learning technologies following the COVID-19 pandemic. The peak number of publications occurred in 2022, reflecting both academic and practical interest in applying artificial intelligence in the education sector, particularly vocational education. This distribution also mirrors the global research dynamics increasingly positioning AI as a key component in technology-based educational innovation.

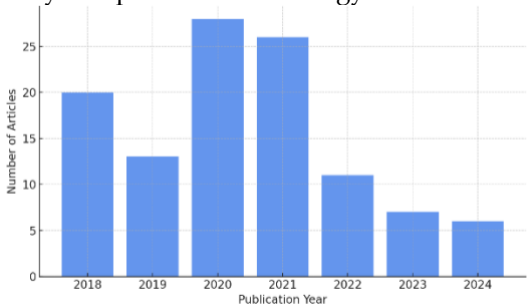

Figure 2. Distribution of main references by year

The analysis based on the country of origin of publications shows that research related to artificial intelligence in adaptive learning within vocational education is dominated by several countries with strong technological research traditions. Figure 3 illustrates the top ten countries contributing the most publications on this topic based on indexing databases. Countries such as the United States, India, and the United Kingdom rank highest in publication numbers across indexing platforms like Elsevier, Routledge, IEEE, and others, demonstrating their commitment to the development of AI-based educational technology (Ghufron, 2018). Contributions from other countries such as China, Germany, and Australia are also significant, reflecting global collaboration and a broad academic interest in this topic. These findings indicate that the implementation of AI in adaptive education has become a cross-national concern, although research remains concentrated in countries with more established technological infrastructure and higher education systems. (Ma & Xu, 2020).

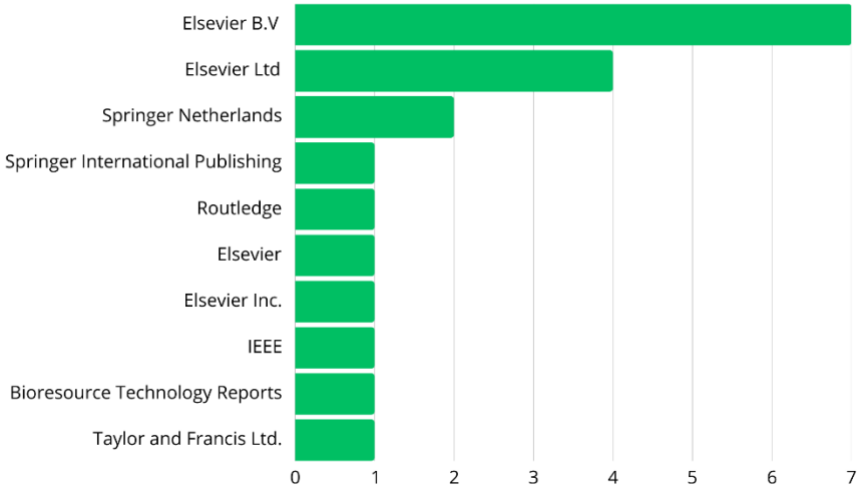

Figure 2. Distribution of main references based on indexing

Bibliometric analysis was conducted to understand the research landscape related to the application of artificial intelligence in adaptive learning, particularly within the context of vocational education. This approach aims to identify publication patterns, keyword distributions, collaboration trends among authors and institutions, as well as the geographic spread of research over a certain period. Using bibliographic data from 41 selected articles and employing VOSviewer software, the study mapped the knowledge structure and the dynamic development of topics within the scientific literature.

The results of this analysis provide a comprehensive overview of the dominant themes emerging in the literature, the most active researchers and institutions in the field, and how the relationships among topics are developed within the scientific framework of technology-based vocational education using artificial intelligence. Visualizations in the form of network maps, keyword clusters, and country distribution of publications are presented to support the interpretation of the position and direction of research development in this area.

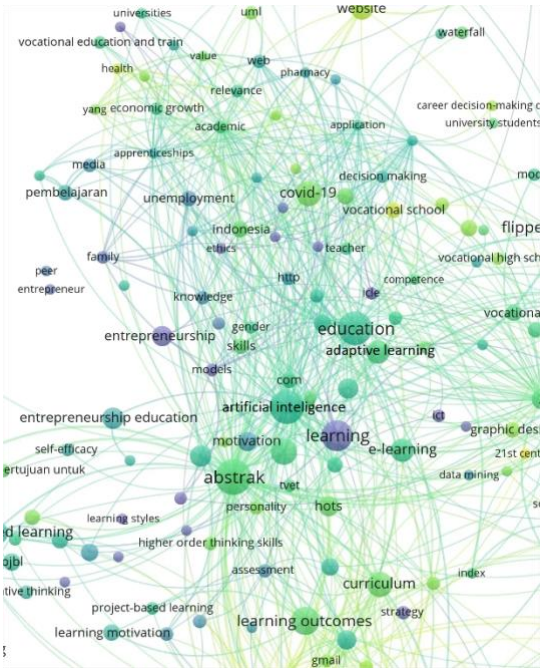

Figure 3. Bibliometric analysis results according to primary references

3.1 Descriptive Results: Publication Trends and Geographical Distribution

The descriptive analysis reveals a consistent increase in publications related to AI-assisted adaptive learning in vocational education from 2018 to 2023. As illustrated in Figure 2, publication output remained relatively modest before 2020 but experienced a significant surge after 2020, coinciding with accelerated digital transformation in education following the COVID-19 pandemic. This trend indicates a growing recognition of AI-driven adaptive learning as a strategic solution for sustaining competency-based learning in disrupted or hybrid educational environments.

In terms of geographical distribution, the results show that research output is dominated by a small number of countries with advanced technological infrastructure and strong research ecosystems. The United States, India, and the United Kingdom emerge as the top contributing countries (Figure 3). Other notable contributors include China, Germany, and Australia. This distribution suggests that countries with established AI research capacity and digital education policies play a central role in shaping the global research agenda on adaptive learning and AI in vocational education.

From an institutional perspective, universities and research centers in these countries often serve as hubs for interdisciplinary collaboration between education, computer science, and engineering. Their dominance may influence the global discourse by prioritizing technologically driven solutions, potentially marginalizing context-specific challenges faced by vocational institutions in developing regions.

3.2 Analytical Results: Thematic Clusters and Keyword Co-Occurrence

Beyond descriptive trends, bibliometric analysis using VOSviewer provides insights into the intellectual structure of the research field. The keyword co-occurrence network (Figure 4) reveals several interconnected thematic clusters. The central cluster, dominated by keywords such as "learning," "artificial intelligence," and "adaptive learning," represents the foundational discourse focusing on AI-enabled personalization, intelligent tutoring systems, and data-driven instructional adaptation. This cluster underscores that most studies conceptualize AI primarily as a technological enabler for learning personalization.

A second cluster is closely associated with vocational education and TVET, including keywords such as "vocational education," "vocational school," "learning outcomes," and "competency." This cluster highlights efforts to contextualize AI technologies within competency-based education systems. Studies in this cluster emphasize practical outcomes such as skill mastery, competency certification, and alignment with labor market demands.

A third cluster connects pedagogical and instructional approaches, including keywords such as "motivation," "curriculum," "project-based learning," and "assessment." This cluster suggests that AI-assisted adaptive learning is increasingly linked to instructional innovation rather than merely technological deployment. For example, several reviewed studies report that adaptive systems enhance learner motivation by providing individualized feedback and adaptive task difficulty, which is particularly relevant in vocational settings with diverse learner profiles.

An emerging cluster includes keywords related to "COVID-19," "online learning," and "blended learning," indicating that the pandemic acted as a catalyst for adopting AI-supported adaptive learning in vocational education. This pattern reflects an unexpected but important shift: AI adoption was not solely driven by long-term innovation agendas but also by immediate institutional needs for resilience and continuity.

3.3 Discussion with Analysis based on results of the bibliometrics review and visualization

The visualization of bibliometric analysis results using VOSviewer reveals the relationships among keywords appearing in the literature on artificial intelligence in adaptive learning within the context of vocational education. In the co-occurrence map, the keyword "learning" appears as the central node, indicating that this topic is the core of all analyzed themes. Surrounding this keyword are other significant nodes such as "adaptive learning," "artificial intelligence," and "education," which form the main closely connected cluster. The large size of these nodes and their central position on the map signify that these keywords not only frequently occur but are also commonly associated with other keywords, highlighting their central role in the development of the literature in this field.

Additionally, other keywords such as "vocational education," "TVETs," "vocational school," and "learning outcomes" form subclusters that demonstrate the connection between AI utilization and the development of adaptive learning within vocational education systems. This reflects that the implementation of intelligent technology in education is not solely focused on the technological approach but also aims to improve the quality of vocational education through contextual and personalized methods. Keywords like "motivation," "curriculum," and "project-based learning" also appear within the network, indicating that AI-based adaptive learning is often associated with innovative teaching approaches that promote student engagement and enhance learning outcomes.

Interestingly, the keyword "COVID-19" also appears in the map, indicating that the pandemic was one of the triggers accelerating the adoption of AI in education. Additionally, the presence of keywords such as "Indonesia," "media," and "learning" suggests contributions from local research within this global ecosystem, as well as the use of terms specific to the Indonesian educational context. This highlights that the discourse on AI in education transcends national and cultural boundaries.

Overall, this visualization reveals that the literature on artificial intelligence in adaptive learning within vocational education develops in multiple directions, encompassing aspects of pedagogy, technology, and education policy. The complexity of the keyword network indicates that research in this field is not isolated but involves the interaction of various disciplines and research focuses, ranging from curriculum development and project-based learning strategies to the implementation of adaptive and personalized intelligent educational technologies. This visualization provides a comprehensive overview of the knowledge structure formed in recent studies and opens opportunities for exploring more specific follow-up themes.

As part of the systematic stage in the literature review, a total of 41 selected scientific articles were classified based on their primary thematic focus related to artificial intelligence (AI), adaptive learning, and vocational education (TVET). This classification process aims to provide a conceptual mapping of

each article's contribution in addressing the main topic, namely: Bibliometric Analysis and PRISMA-Based Meta-Analysis of AI-Assisted Adaptive Learning from the Perspective of Vocational Education.

The references reviewed span the period from 2018 to 2023 and demonstrate a broad thematic coverage. Based on content and keyword analysis of each article, the classification was divided into three main groups: Artificial Intelligence Focus, TVET Focus, and Adaptive Learning, Integration, and Educational Frameworks Focus.

Table 2. Publication Classification and Discussion Focus

Artificial Intelligence Focus	
1	(Anwar, 2021b)
2	(Muhammad, 2019)
3	(Supriyanto et al., 2019)
4	(J. Liu et al., 2021)
5	(Kusumawati, 2018)
6	(Carolus et al., 2023)
7	(Ghufron, 2018)
8	(Dasgupta, 2018)
9	(Anwar, 2021a)
10	(Khalil et al., 2021)
11	(Hidayat et al., 2021)
12	(Ma & Xu, 2020)
13	(Callejas et al., 2023)
14	(Adnan & Anwar, 2020)
15	(Castro, 2019)
16	(Medan et al., 2018)
17	(Firzatullah, 2021)
18	(Supriyanto et al., 2019)
19	(Utami et al., 2023)
20	(Hidayat et al., 2021)
21	(Reigeluth & An, 2020)
22	(Dharma et al., 2020)
23	(Debnath & Roy, 2021)
24	(Fricticarani et al., 2023)
25	(Alfiah et al., 2019)
26	(Widjanarko et al., 2021)
TVET Focus	
27	(Ratnaningtyas, 2018)
28	(Agustini et al., 2018)
29	(Mubai et al., 2021)
30	(Dyah et al., 2022)
31	(Kesuma et al., 2022)
32	(Jalinus et al., 2021)
33	(Choy & Yeung, 2022)

Focus on Learning, Adaptive, and Integration	
34	(Maier et al., 2019)
35	(Muafi et al., 2021)
36	(Gleason, 2018)
37	(Hattie & Gregory, 2018)
38	(Omar et al., 2019)
39	(Christopoulos & Sprangers, 2021)
40	(D. Liu, 2022)
41	(Sarmas et al., 2020)

The first group, Artificial Intelligence Focus, includes 26 articles that directly discuss the role and application of AI within the context of education or learning systems (Dasgupta, 2018). Articles in this group generally discuss technological approaches such as machine learning, recommendation systems, intelligent tutoring systems, and the implementation of AI for personalized learning. This reflects a strong interest from the academic community in the potential of AI as a transformative innovation in education, both from technical and pedagogical perspectives (Khalil et al., 2021).

The second group, TVET Focus, consists of 7 articles that specifically address issues in vocational education, including competency enhancement, vocational curriculum development, and 21st-century skills requirements within the vocational education environment (Dyah et al., 2022). These articles provide an important contextual foundation regarding the challenges and opportunities within the vocational education system, which serves as the primary setting for the implementation of AI-based adaptive learning models (Maier et al., 2019).

The third group, Adaptive Learning, Integration, and Framework Focus, consists of 8 articles that examine how adaptive learning systems are designed and integrated into education, whether through pedagogical approaches, conceptual frameworks, or meta-analyses on the effectiveness of adaptive strategies in the learning process (Sarmas et al., 2020). Some articles in this group also bridge the utilization of technology with data-driven educational approaches (Gleason, 2018).

The results of this classification indicate that the majority of the literature (more than half) remains concentrated on the technological aspects of AI, while discussions integrating adaptive approaches within the vocational education framework are still evolving. This presents further opportunities for exploration in combining AI, adaptive pedagogical approaches, and learning practices within the vocational education context in a more comprehensive and contextualized manner.

3.4 Implications for Vocational Education Policy and Practice

The identified themes have direct practical implications for vocational education stakeholders. First, the dominance of AI-driven personalization themes suggests that policymakers should prioritize adaptive learning systems that support individualized competency pathways, rather than uniform digital platforms. This is particularly important for addressing skills gaps and heterogeneous learner readiness in vocational education.

Second, the concentration of research output in technologically advanced countries highlights the need for context-sensitive policy transfer. While AI-based adaptive learning models developed in the United States or the United Kingdom offer valuable insights, vocational education systems in developing countries may require localized adaptation, considering infrastructure constraints and industry contexts.

Practically, reviewed studies provide examples such as AI-based intelligent tutoring systems that recommend personalized learning modules based on students' practical performance, or adaptive

assessment systems that dynamically adjust task complexity to match learner competency levels. These examples demonstrate how AI can support continuous competency tracking and formative assessment in vocational programs.

3.5 Critical Reflections and Emerging Patterns

One unexpected finding is the relatively limited number of studies that explicitly evaluate long-term learning outcomes or the workforce impact of AI-assisted adaptive learning in vocational education. While many studies report improved engagement or short-term learning gains, fewer address sustained competency development or employability outcomes. This suggests a research gap in longitudinal evaluation. Additionally, the bibliometric analysis reveals a technological bias, with a stronger emphasis on system development than on pedagogical integration. This imbalance indicates the need for future research to bridge AI innovation with vocational pedagogy, curriculum alignment, and instructor professional development.

3.6 Biases and Limitations of the Bibliometric Analysis

Several limitations must be acknowledged. First, the reliance on English-language publications may exclude relevant studies published in other languages, particularly from regions where vocational education plays a critical role. Second, database selection bias exists, as Scopus prioritizes high-impact journals, while Google Scholar includes a broader but less curated range of sources. Although triangulation across databases was applied, differences in indexing coverage may influence publication counts and thematic visibility. Despite these limitations, the combined PRISMA-based SLR and bibliometric approach provides a robust overview of research trends and thematic directions in AI-assisted adaptive learning within vocational education.

4. CONCLUSION

This study systematically examined research trends in AI-assisted adaptive learning within vocational education using a PRISMA-based systematic literature review and bibliometric analysis. The findings reveal that research on this topic has increased significantly since 2020, reflecting growing scholarly interest and institutional attention. The dominant themes focus on artificial intelligence, adaptive learning systems, and competency-based vocational education, with strong connections to personalization, learner motivation, and technology integration. Additionally, research contributions are geographically concentrated in technologically advanced countries such as the United States, India, and the United Kingdom, which largely shape the global discourse on AI-driven adaptive learning. Despite these contributions, the study has several limitations, including reliance on publications indexed in Scopus, Semantic Scholar, and Google Scholar and the restriction to English-language articles, which may limit the comprehensiveness of the analysis and underrepresent research from other regions. Therefore, future research should expand database coverage, include multilingual publications, and conduct empirical and longitudinal studies to examine the long-term impact of AI-assisted adaptive learning on competency development, employability, and pedagogical integration across diverse vocational education contexts.

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