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BIBLIOMETRIC ANALYSIS OF FUTURE RESEARCH TRENDS AND DIRECTIONS: TRANSFORMING EDUCATION WITH ARTIFICIAL INTELLIGENCE (AI)

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Abstract: This study aims to explore emerging trends and future research directions in the integration of Artificial Intelligence (AI) for educational transformation through bibliometric analysis. The data analysed was taken from the SCOPUS database, covering 537 documents published between 1989 and 2024. The findings show a significant increase in the number of publications since 2017, reflecting the growing interest in the application of AI in education. The countries with the highest contributions were China and the United States, which also had the highest citation impact. The analysis shows that key research themes include personalised learning, adaptive learning systems, big data analytics, as well as advanced AI technologies such as machine learning and generative models (e.g., ChatGPT). In addition, the keyword co-occurrence network revealed the interdisciplinary nature of research in this area, with a strong focus on digital transformation and data-driven learning. The study also identifies significant challenges related to the digital divide and student data privacy, which need to be addressed in future broader AI implementations. The findings offer valuable insights for researchers, educators and policymakers, and provide practical recommendations to effectively utilise AI in creating inclusive and sustainable educational environments.

Keywords: Adaptive Learning; Artificial Intelligence; Bibliometric Analysis; Educational Innovation; Educational Transformation.

INTRODUCTION

The rapid advancement of technology in the 21st century has brought significant changes in various sectors, including education. (Among these technological advances, Artificial Intelligence (AI) stands out as a revolutionary force with the potential to redefine the traditional education paradigm (Kurban & Şahin, 2024). AI technologies, such as machine learning, natural language processing, and computer vision, are increasingly being integrated into education systems to enhance learning experiences, personalise instruction, and simplify administrative processes (Koh, 2024; Varoquaux et al., 2015; S. Wang et al., 2023). This integration of AI in education is not just a trend, but a profound shift towards a more data-driven and individualised learning environment, which promises to meet the various needs of students and educators.

The influence of AI in education covers multiple dimensions (Chan & Colloton, 2024; Koh, 2024; Kurban & Şahin, 2024; Labadze et al., 2023). On the

one hand, AI-powered adaptive learning systems can tailor educational content to the pace and learning style of individual students, thereby enhancing engagement and understanding. Intelligent tutoring systems provide personalised feedback and support, mimicking the one-on-one attention traditionally offered by human tutors. The system uses complex algorithms to analyse student performance data and adapt teaching strategies in real-time, ensuring that each learner receives a tailored educational experience. Furthermore, AI-driven assessment tools offer an objective and consistent method of evaluation, reducing the biases inherent in human judgement (Bengsch, 2024; Verma et al., 2024).

On the administrative side, AI facilitates operational efficiency through automated assessment, data management, and predictive analyses that help identify at-risk students and design timely interventions. These applications not only improve learning outcomes but also optimise the operational efficiency of educational institutions (Y. Wang & Wang, 2022). For example, AI-powered chatbots and virtual assistants can handle routine queries from students, allowing faculty more time to focus on more important tasks (Labadze et al., 2023; Ramandanis & Xinogalos, 2023). Additionally, predictive analytics can help with resource allocation, ensuring that support services are directed to where the need is greatest, thus improving overall institutional effectiveness.

Despite its promising potential, the integration of AI in education is fraught with challenges and unresolved issues (Richardson & Clesham, 2021). One significant issue is the digital divide, which can exacerbate existing inequalities in access to AI-enhanced educational resources. Schools and institutions in underprivileged areas may not have the necessary infrastructure to implement AI technologies, thus widening the educational gap between different socioeconomic groups. These inequalities raise ethical concerns about equitable access to high-quality education and risk perpetuating existing social inequalities.

Furthermore, there are ethical considerations regarding data privacy and security, as AI systems often require large amounts of student data to function effectively (Prastiwi & Nazief, 2023). The collection, storage, and analysis of such data pose significant privacy risks, making it important to establish robust data protection measures. The potential for AI to inadvertently reinforce existing biases and stereotypes through biased algorithms is another important issue that must be addressed to ensure fairness and inclusivity in AI-driven educational environments.

Another important issue is the readiness of educators and institutions to adopt AI technologies. Successful implementation of AI in education requires not only technological infrastructure but also a paradigm shift in teaching methodologies and curriculum design. Educators must be trained to work with AI tools, and curricula must be customised to incorporate these new technologies in a meaningful way. However, there is an important gap in research that addresses how best to facilitate this transition and ensure that the benefits of AI are evenly distributed. Professional development programmes designed to equip educators with the necessary skills and knowledge to

integrate AI into their teaching practices are essential yet unexplored in the current literature.

Given these challenges, there is an urgent need for a comprehensive analysis of existing research to identify trends, gaps, and future directions in the field of AI in education. Bibliometric analysis offers a systematic approach to evaluate the scientific landscape, providing insights into the volume, growth, and impact of research in this domain (Baber et al., 2023). By analysing patterns in publication data, citation networks, and key research themes, bibliometric studies can highlight which areas of AI in education are well researched and which are less explored (Harto et al., 2022; Rojas-Sánchez et al., 2023). This, in turn, can guide future research efforts, policy making, and practical implementation of AI in educational settings.

Bibliometric analyses can also reveal the interdisciplinary nature of AI research in education, exposing collaborations between computer scientists, educators, psychologists and other stakeholders. Understanding these collaborative networks can help identify key influential figures and thought leaders in the field, fuelling opportunities for cross-disciplinary research and innovation. Additionally, bibliometric studies can provide insights into the geographical distribution of AI research in education, highlighting regions that are leading the way and regions that require more attention and support.

While the integration of Artificial Intelligence (AI) in education has shown significant potential in improving learning personalisation and operational efficiency, there are several challenges that need to be addressed. One of the emerging academic concerns is related to the gap in technology access between schools in developed and underdeveloped regions. Uneven implementation of AI has the potential to widen the digital divide, resulting in inequity in access to quality education. In addition, there are concerns related to student data privacy, especially when AI systems require massive collection and analysis of personal data. These challenges raise critical questions about how technology can be inclusively and responsibly implemented in educational settings.

The significance of this research lies in its attempt to map the current research trends and future directions in the application of AI for educational transformation. Utilising bibliometric analysis, this study aims to identify well-researched areas as well as uncover research gaps that need to be further explored. The results of this study are expected to provide strategic insights for educators, policymakers, and researchers to maximise the potential of AI in creating a more adaptive and inclusive education system.

The novelty of this study lies in its thorough analysis of global trends over the past 35-year period (1989-2024) regarding the application of AI in education. The study not only identifies key emerging themes, but also offers insights into the potential for future research, especially in the post-pandemic context of COVID-19, where online and hybrid learning are gaining increasing attention. As such, this study makes a novel contribution by linking digital transformation in education with contemporary challenges and sustainable best practices.

This bibliometric study aims to explore emerging trends and future research directions in AI for educational transformation. The specific objectives of this study are: Mapping scholarly research outputs and identifying key research themes in the field of AI in education and identifying research gaps and unexplored areas that require further investigation. Provide insights into the future directions and potential applications of AI in education based on current research trends.

By achieving these goals, this research seeks to contribute to a deeper understanding of how AI can be utilised to effectively transform education. It aims to inform educators, policymakers and researchers about the current status of AI in education and the critical areas that need attention to maximise its benefits and mitigate its challenges. Through detailed bibliometric analyses, this research will uncover the trajectory of AI in education, revealing how past and current research efforts have shaped the field and what future directions hold the most promise.

METHODS

Bibliometric analysis is a research method used to quantitatively evaluate academic literature in a particular field. It involves statistical analysis of books, articles, and other publications to uncover patterns, trends, and relationships (Kumar et al., 2023; Sarea, 2020). This methodology provides insights into the development and impact of a research field, helping to map the scientific landscape and identify influential works and emerging topics. This research methodology is designed to systematically analyse scholarly outputs on the topic of Artificial Intelligence (AI) in educational transformation using bibliometric analysis. The data source for this analysis is SCOPUS, a comprehensive abstract and citation database that provides a wide range of academic literature across multiple disciplines (Cecilia-Martín et al., 2020). This section outlines the data collection process, search strategy, and bibliometric techniques used to achieve the research objectives.

Data Collection

The data for this bibliometric study was taken from the SCOPUS database. SCOPUS was chosen due to its extensive coverage of peer-reviewed literature and strong citation analysis capabilities (Baas et al., 2020). The database includes a variety of documents such as journal articles, conference papers and reviews, making it an ideal source for comprehensive bibliometric analyses. A search was conducted to capture all relevant literature relating to AI and educational transformation.

Search Strategy

To ensure the acquisition of relevant documents, a well-defined search strategy was used. Search terms were carefully selected to cover the core aspects of the research topic. The search queries used in SCOPUS are as follows:

KEYWORDS ("artificial intelligence" OR ai) AND KEYWORDS (education AND transformation)

This set of searches was designed to identify documents that included the terms "artificial intelligence" or "AI" along with "education" and "transformation" in their title, abstract or keywords. The rationale behind this search strategy is to capture the broad spectrum of literature

that addresses the application of AI in transforming educational practices, processes and systems.

Data Extraction

The search query returned a total of 537 documents. These documents constitute the data set for bibliometric analysis. The data extraction process involved downloading the metadata of these documents, which included information such as title, author, affiliation, year of publication, source title, document type, keywords, abstract, and number of citations. The metadata serves as the basis for subsequent bibliometric analysis and visualisation.

Data Visualisation

To facilitate the interpretation of bibliometric data, various visualisation techniques are used. Tools such as VOSviewer and Bibliometrix are used to create visual representations of bibliometric networks, including co-authorship networks, keyword co-occurrence maps, and citation networks. These visualisations provide a clear and intuitive understanding of complex relationships and patterns in the data.

By following this methodology, this study aims to provide a comprehensive understanding of the current status of research on AI in educational transformation. The results will offer valuable insights and practical recommendations to advance the field, with the aim of optimising the use of AI to create an educational environment that is not only effective and efficient but also equitable and inclusive

RESULT

General Information and Growth Trends

The general information gathered by the researchers in this study is described in table 1 which provides a comprehensive overview of bibliometric data on AI in educational transformation from 1989 to 2024, sourced from SCOPUS. It includes 537 documents from 376 diverse sources, reflecting a strong annual growth rate of 14.87%. The average document age is 2.37 years, which indicates the novelty of the research, with an average of 6.49 citations per document and a total of 18,572 references. Keyword Plus and Author Keyword highlight a wide thematic range, with 2,302 and 1,493 terms respectively. The research community consisted of 1,617 authors, with 107 producing self-authored work, while the average co-authors per document was 3.19, and 17.32% of documents featured international collaborations. This data underscores a dynamic, collaborative and rapidly growing field with significant global interest and diverse research contributions.

Table 1
Key information on publication collections

Description	Results
KEY INFORMATION ABOUT THE DATA	
Time period	Year 1989:2024
Source (Journal, Book, etc)	376
Document	537
Annual Growth Rate %	14,87
Document Average Age	2,37
Average citations per document	6,49
Reference	18572
DOCUMENT CONTENT	
Keyword Plus (ID)	year 2302
Author Keywords (DE)	1493
AUTHOR	
Author	1617
Author of a document written by one author	107
AUTHOR COLLABORATION	
Documents written by one author	112
Co-Author per Document	3,19
International co-authorship %	17,32

The data depicted in Table 1 presents a comprehensive picture of the scholarly landscape regarding AI in educational transformation. The increasing number of documents and significant annual growth rate reflect the growing academic and practical interest in utilising AI to improve education. The relatively young average age of the documents and the variety of sources and keywords indicate that this is a dynamic and evolving field, characterised by continuous innovation and exploration.

The moderate average number of citations indicates that although the field is growing, there is still room to increase its impact and recognition within the wider academic community. The substantial number of references highlights the interconnected nature of the research, indicating that academics are building on a solid foundation of existing knowledge. The balance between self-authored and collaborative work, along with the significant level of international co-authorship, underlines the collaborative nature of research in this area. These collaborations are critical to addressing complex global challenges in education through AI.

Figure 1 below illustrates the annual publication growth of documents related to AI in education transformation from 1989 to 2024. The graph shows a relatively flat trend from 1989 to around 2016, with minimal annual publications. A noticeable increase begins around 2017, with a sharp upward trend continuing until 2022. A peak in the number of publications occurs in 2023, followed by a slight decline in 2024.

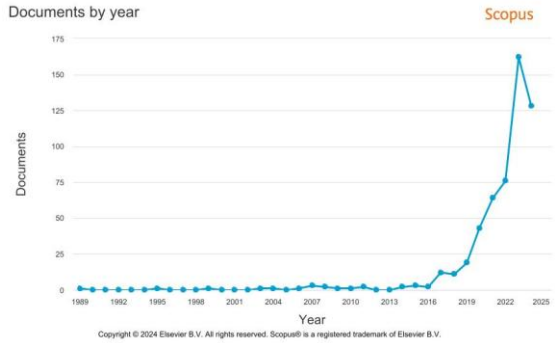

Figure 1
Annual Publication Growth

According to the data, the dramatic increase in publications from 2017 onwards reflects the growing interest and recognition of the importance of AI in transforming education. The sharp increase in documents from 2017 to 2023 suggests that the field has gained substantial momentum, likely fuelled by advances in AI technology and a greater focus on innovative educational practices.

The peak in 2023 indicates that research in this field reached its highest level of activity, possibly due to the culmination of several factors such as increased funding, international collaboration, and a higher global emphasis on educational technology in response to the COVID-19 pandemic. The slight decline in 2024 may indicate a stabilisation phase or temporary decline as the field adjusts to its recent rapid growth.

Contribution by Country

Figures from SCOPUS illustrate the number of documents related to AI in educational transformation by country or region (figure 1). The figure shows that China leads with the highest number of documents, followed by the Russian Federation, the United States, and India. The UK, Spain, Mexico, Ukraine, Malaysia and Italy also contribute significantly to the body of research in this area.

On the other hand, Table 2 lists the countries with the highest number of citations for their publications in AI and educational transformation. China again leads with 587 citations, followed by the US with 266 citations. Italy (188), Malaysia (177), Australia (146), and Saudi Arabia (133) also have a considerable number of citations. The list continues with Cyprus (110), Mexico (71), India (70), and the UK (70).

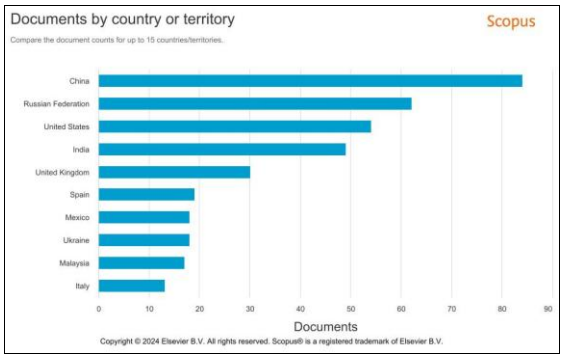

Figure 2.
Most Productive Countries

Table 2.
Most Cited Countries

NOT	Country	Number of Citations
1	China	587
2	United States of America	266
3	Italy	188
4	Malaysia	177
5	Australia	146
6	Saudi Arabia	133
7	Cyprus	110
8	Mexico	71
9	India	70
10	United Kingdom	70

The figure depicting the most productive countries and Table 1 showing the most cited countries provide a comprehensive view of the global contribution and influence in AI research for educational transformation. China

leads prominently in the number of documents and total citations, indicating not only a high volume of research output but also significant impact and recognition in the field. The US, although also highly productive, stands out with a substantial number of citations, reflecting influential research. European countries such as Italy and the UK, along with Asian countries such as Malaysia and Saudi Arabia, showed strong contributions in terms of both productivity and impact, highlighting the diverse and global interest in the application of AI in education.

The data reveals that although countries such as Russia and India produce a large number of documents, their impact in terms of citations is relatively lower, indicating varying degrees of influence. Emerging research centres such as Cyprus and Mexico, despite having fewer publications, show a significant number of citations, indicating the high quality and recognition of their research. The substantial level of international collaboration further underlines the interconnected and co-operative nature of this research field, which contributes to its dynamic and constantly evolving landscape. Overall, this analysis highlights the leading role of China and the diverse international contributions shaping the future of educational transformation through AI.

Author Contribution

Table 3 identifies the ten most relevant authors, with Zhang J leading the way with five publications, followed by Kumar A, Liu H, Liu J, and Wang Y, each with four articles. This indicates a vibrant and collaborative research community, with significant contributions from diverse geographical and institutional backgrounds. This combination of highly cited documents and prolific authors underscores the richness and depth of the research landscape in AI and educational transformation. Table 4, on the other hand, lists the most cited documents related to AI in educational transformation, highlighting significant contributions such as the study of Tilli et al. (2023) on ChatGPT, which leads with 459 citations and an impressive 229.50 citations per year. Other notable works include Chassignol et al. (2018) on AI trends in education, Brunetti et al. (2020) on the challenges of digital transformation, and Ratten (2020) on the impact of COVID-19 on education. These highly cited papers reflect areas of critical interest and influential research in the field.

Table 3.
10 Most Relevant Authors

NOT	Author	Article
1	ZHANG J	5
2	A KUMAR	4
3	LIU H	4
4	J.LIU J.	4
5	WANG Y	4
6	A BOZKURT	3
7	CHEN-XI	3
8	KOLGATINA LS	3
9	LI Z	3
10	LIU L	3

Table 4.
Most Cited Documents

Paper	DOI	Number of Citations	TC per Year
Tlili and friends (2023)	What if the devil is my guardian angel: ChatGPT as a case study of chatbot use in education	459	229.50
Chassignol and friends (2018)	Artificial Intelligence Trends in Education: A Narrative Overview	301	43.00
Brunetti et al. (2020)	Digital transformation challenges: strategies emerging from a multi-stakeholder approach	185	37.00
Rats (2020)	Coronavirus (Covid-19) and the entrepreneurship education community	145	29.00
Mehmood and friends (2017)	UTiLearn: A Comprehensive Personalised Teaching and Learning System for a Smart Society	117	14.63
Stoumpos et al. (2023	Digital Transformation in Healthcare: Technology Acceptance and Application	110	55.00
Qureshi and friends (2021)	Digital Technology in Education 4.0. Can Digital Technology Improve Learning Effectiveness? Systematic Literature Review	95	23.75
Okunlaya et al. (2022)	Artificial intelligence (AI) library services are an innovative conceptual framework for the digital transformation of university education	76	25.33
Leahy and friends (2019)	Digital boundaries: Imagining the impact of future technologies on the classroom	57	9.50
Cantú-Ortiz et al. (2020)	Artificial intelligence education strategy for digital transformation	56	Date 11.20

The most cited documents reflect important areas of interest and influential research in AI and educational transformation. The leading paper on Tlili et al. (2023)'s use of ChatGPT in education signalled the growing importance of conversational AI in enhancing learning experiences. Chassignol et al. (2018) provide a broad overview of AI trends, indicating fundamental references in the field. The diverse topics of other widely cited papers, ranging from digital transformation strategies to the impact of COVID-19 on education, underscore the multifaceted applications and significant global events affecting AI research in education.

The list of top authors highlights the key contributors driving research in AI and educational transformation. Zhang J, with the most publications, appears to be a leading figure, significantly influencing the field. The presence of many authors with a high number of publications indicates a collaborative and active research community. The diversity of authors also indicates a wide geographical and institutional representation, which

contributes to the richness and depth of the research.

Keyword Analysis

The keyword co-occurrence network visualisation in Figure 2, generated using VOSviewer, offers a detailed view of the thematic structure and focus areas of research in AI and educational transformation. Major keywords such as "artificial intelligence" and "digital transformation" stand out clearly, indicating their importance in the research field. These key nodes show that most research revolves around these core concepts, which underlines their fundamental role in educational transformation.

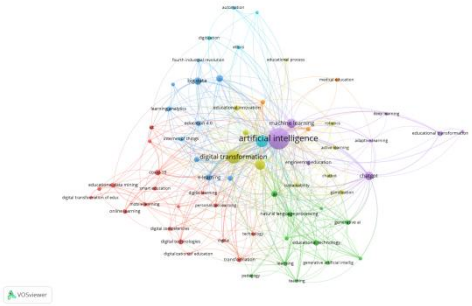

Figure 2.
Keyword Co-Occurrence Network Visualisation

The keyword co-occurrence network generated through VOSviewer revealed five major clusters in AI research for education:

a) Cluster 1 (Green): Focuses on educational technology, pedagogy, learning, and teaching. This cluster shows a strong interest in the application of AI to enhance more effective teaching and learning methodologies.
b) Cluster 2 (Purple): Centred on advanced AI techniques such as machine learning, deep learning, and ChatGPT. This theme is relevant to the development of adaptive learning systems that can adjust to the individual needs of students.
c) Cluster 3 (Blue): Covers big data analytics, learning 4.0, and the Internet of Things, which shows trends in utilising data to improve the quality of learning.
d) Cluster 4 (Red): Focuses on online learning, mobile learning and educational data mining, which are increasingly important in the post-pandemic context of distance learning.
e) Cluster 5 (Yellow): Highlights new trends in sustainability, AI ethics, and natural language processing, reflecting increased attention to the responsible use of AI in education.

This visualisation reveals several different clusters, each of which represents a specific research area. The green cluster, which focuses on education technology, pedagogy, learning, and teaching, highlights significant interest in how AI can improve teaching methodologies. The purple cluster centres around advanced AI techniques such as machine learning, deep learning, adaptive learning, and ChatGPT, demonstrating its applicability in creating personalised learning environments. The blue cluster includes big data, learning analytics, education 4.0, and the Internet of Things, reflecting a strong interest in utilising data to drive educational improvement. The red cluster emphasises digital technology, online learning, mobile learning and educational data mining, which illustrate the ongoing efforts to integrate digital tools into education, especially relevant during the COVID-19 pandemic. The yellow cluster covers sustainability, natural language processing

and technology, showcasing emerging trends and innovative applications of AI in education.

The interconnectedness of the keywords illustrates the interdisciplinary nature of research in this field. The large number of linkages suggests that advances in one area, such as machine learning, often influence related areas such as personalised learning and educational innovation. The presence of keywords such as "ChatGPT" and "generative AI" in the purple group highlights the growing interest in how conversational AI and generative models can be used in educational environments, indicating an emerging trend.

Future Research Potential in Character Education and Local Wisdom

Based on the findings and discussion presented, several avenues for future research in the field of AI and educational transformation emerged. These potential research directions are informed by key themes, emerging trends, and gaps identified in the current literature.

Integration of AI and Educational Technology: The centrality of buzzwords such as "artificial intelligence" and "digital transformation" underscores the fundamental role that these concepts play in educational research. Future studies could explore more deeply how AI can be integrated with existing educational technologies to create holistic learning environments. This includes investigating best practices for implementing AI-driven tools in classrooms, understanding barriers to adoption, and developing frameworks that educators can use to improve learning outcomes.

Personalised and Adaptive Learning Systems: The advantages of advanced AI techniques such as machine learning and deep learning in keyword networks highlight their important role in personalised education. Future research could focus on developing and refining adaptive learning systems that cater to individual students' needs, learning pace and preferences. Studies could also explore the long-term impact of these systems on student engagement, retention, and academic performance.

Big Data and Learning Analytics: With keywords such as "big data" and "learning analytics" forming a significant cluster, future research could investigate how large data sets can be used to gain insights into student behaviour and learning patterns. Researchers can investigate how predictive analytics can be used to identify at-risk students early and provide timely interventions. In addition, exploring the ethical considerations and data privacy issues associated with the use of big data in education will be crucial.

New Technologies and Innovations: The presence of terms such as "ChatGPT," "generative AI," and "natural language processing" in the network indicates a growing interest in these advanced technologies. Future research could examine the efficacy and impact of conversational AI and generative models in educational contexts. This includes studying how these technologies can be used to improve student-teacher interactions, automate administrative tasks, and provide personalised guidance and support.

Sustainability and Ethical AI: Groups that include keywords such as "sustainability" and "ethical" indicate an

emerging focus on the responsible use of AI in education. Future research could investigate sustainable AI practices that minimise environmental impact and ensure equitable access to AI-driven educational tools. Additionally, exploring the ethical implications of AI in education, such as algorithmic bias, data privacy, and the digital divide, will be critical to ensuring that AI equitably benefits all students.

The potential for future research in AI and educational transformation is vast and diverse. By exploring these identified areas, researchers can contribute to a deeper understanding of how AI can be utilised to create more effective, inclusive and innovative educational environments. This will ultimately help educators and policymakers make informed decisions to improve learning experiences and outcomes for students around the world.

DISCUSSION

This discussion of bibliometric results on education transformation shows significant changes driven by the integration of Artificial Intelligence (AI). From the data analysed, various trends and innovations are revealed that show how AI has shaped the way education is delivered and personalised. For example, AI is used to support adaptive learning systems that enable learning experiences to be more effective and tailored to students' individual needs (Kurban & Şahin, 2024). These systems have been shown to increase student engagement and facilitate deeper learning (Koh, 2024).

This research also highlights the use of AI in digital transformation, including the development of tools such as ChatGPT that are increasingly used to enhance student and teacher interactions (Tlili et al., 2023). This technology is able to simulate human tutor-like interactions, providing personalised and immediate feedback, which significantly improves learning efficiency (Bengsch, 2024).

On the other hand, this educational transformation is also faced with ethical challenges such as algorithmic bias and student data privacy (Prastiwi & Nazief, 2023). While AI has great potential to reduce educational disparities, the digital divide may widen the gap between schools that have access to high technology and those that do not (Richardson & Clesham, 2021). Therefore, further research is needed to ensure that AI integration is done in an inclusive and equitable way (Verma et al., 2024).

CONCLUSIONS

The data collected on AI in education transformation reveals a dynamic and rapidly evolving research landscape, characterised by significant global contributions and high levels of collaboration. China leads in both research output and citation impact, demonstrating its leading role in the field, while other countries such as the US, Italy, Malaysia, and Saudi Arabia also make substantial contributions. Key themes such as digital transformation, personalised learning, and advanced AI technologies such as machine learning and ChatGPT stand out, reflecting the diverse applications and ongoing innovations in this domain. The keyword co-occurrence network underscores the interconnectedness of different research areas, highlighting emerging trends and potential for future exploration. Overall, the findings demonstrate a vibrant and interdisciplinary research community dedicated to harnessing the transformative

potential of AI in education, paving the way for continued progress and impactful applications in this important sector.

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