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Global Educational Data Mining Research Trends in Education

A Bibliometric Analysis and Implications for Transformational Leadership in Education

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ABSTRACT

The education sector faces new challenges and opportunities in the digital era of big data and rapid technological advancement. This study aims to perform a comprehensive bibliometric analysis of global research trends in Educational Data Mining (EDM) from 2012 to 2024 and examine their implications for transformational leadership in education. We extracted relevant EDM publications from the Dimensions database using the PRISMA methodology and analyzed publication patterns, collaboration networks, and methodological trends. The analysis reveals a marked increase in EDM-focused research interest over time, accompanied by growing international and inter-institutional collaborations and evolving research approaches. Findings suggest that transformational educational leaders can leverage EDM insights, such as data-driven and predictive analytics, to enhance teaching effectiveness, encourage participative decision-making, and foster innovative learning environments. This bibliometric review provides critical insights for educators and policymakers on integrating EDM with transformational leadership practices and encourages further research on data-informed leadership in education.

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Introduction

In the digital era characterized by rapid technological advancements and an ever-increasing volume of data, the education sector faces significant challenges and opportunities [1]. Educational Data Mining (EDM) has emerged as an innovative solution to leverage big data to enhance the quality of education [2]. EDM is defined as the process of analyzing data to extract valuable information and patterns from data collected in educational contexts [3]. This process involves advanced analytical techniques, including machine learning algorithms and statistical analysis [4], and predictive modeling [5], which together can inform decision-making [6], improve teaching effectiveness [7] and enhance student learning experiences [8].

As the complexity of educational systems and the diverse needs of students increase, transformational leadership becomes increasingly important. Academic leaders who adopt a transformational leadership style can inspire and motivate their staff, create a clear vision, and foster innovation within school environments [9]. Such leadership is highly relevant in the context of EDM, where leaders can utilize data analysis to formulate more effective strategies that are responsive to students' needs and the challenges faced in education [10]. Based on this background, this article aims to present a comprehensive bibliometric analysis of global research trends in EDM from 2012 to 2024. The study will use the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) methodology to evaluate and analyze relevant publications from leading academic databases, particularly Dimension. This article will provide a clear overview of developments and directions in this field by identifying publication patterns, researcher and institutional collaborations, and methodological trends in EDM research.

This study employed the PRISMA framework to ensure methodological transparency. A structured selection process included identification, screening, eligibility, and inclusion phases. The Dimensions database was chosen for its wide coverage and open-access nature. Although not as extensively indexed as Scopus or Web of Science, Dimensions includes a growing body of relevant educational research. Comparative checks were made to ensure major EDM publications in Scopus/WoS were also captured, validating its comprehensiveness.

The analysis is expected to offer deep insights for educators, researchers, and educational leaders regarding the importance of EDM in the context of transformational leadership. Additionally, the article will discuss the implications of EDM for leadership practices, including how leaders can use data to enhance teaching and learning effectiveness, encourage active participation in decision-making, and create adaptive and responsive learning environments [11]. Thus, this article aims to foster a better understanding of integrating Educational Data Mining in educational leadership and stimulate further research.

Materials and Methods

This study employed a systematic bibliometric approach guided by the PRISMA 2020 framework [12] to identify and analyze scholarly publications related to Educational Data Mining (EDM) within the educational context. Data were extracted from the Dimensions platform (https://app.dimensions.ai/) on October 14, 2024. The PRISMA methodology was selected due to its structured and transparent approach to literature identification, screening, eligibility assessment, and inclusion, ensuring the rigor and reproducibility of the analysis [13][14].

A. Eligibility Criteria

Publications were included if they met the following criteria:

1. Written in English
2. Published between 2010 and 2024
3. Indexed in the Dimensions database
4. Focused on Educational Data Mining within the context of education

Publications not written in English, those unrelated to education, and those outside the specified time frame were excluded.

B. Information Sources and Search Strategy

The initial search used the keyword "Educational Data Mining", resulting in 27,850 records. The search strategy was designed to ensure comprehensive topic coverage while maintaining relevance to the research objectives.

C. Selection Process

Following PRISMA guidelines, a four-stage filtering process was applied:

1. Identification: Initial retrieval of 27,850 records using the keyword "Educational Data Mining".
2. Screening: Filtered by publication year (2010–2024), reducing the dataset to 26,892 records.
3. Eligibility: Limited to articles and conference papers, yielding 16,576 records.
4. Inclusion: Final refinement using the keyword "education" to ensure thematic relevance, resulting in 7,454 publications included for bibliometric and network analysis.

The complete flow of the selection process is illustrated in Fig. 1, which follows the PRISMA 2020 flow diagram format.

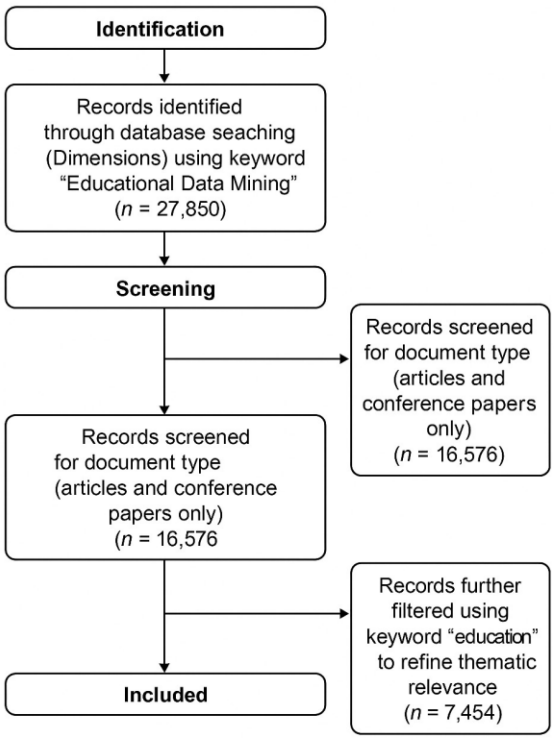


Fig. 1. PRISMA used in this study

D. Data Analysis

Bibliometric indicators include publication trends, international collaboration patterns, methodological approaches, and thematic distributions. Coauthorship networks and author influence were also analyzed to identify key contributors to the EDM field, particularly regarding transformational leadership in education.

Results

The bibliometric analysis results reveal intriguing trends in EDM research from 2012 to 2024. From the total of 7,454 filtered publications, we found that interest in EDM among researchers and education practitioners has significantly increased. This rise reflects a growing awareness of the importance of utilizing big data to enhance teaching and learning processes and support data-driven decision-making.

A. Trends in Educational Data Mining Publications

Data analysis shows a clear fluctuation in the number of publications per year. While the number of publications remained relatively stable at the beginning of this decade, there was a significant spike in 2020, which can be attributed to the heightened interest in educational technology due to the COVID-19 pandemic. Many academic institutions transitioned to remote learning during this period, creating a need to explore new methods for analyzing student data and optimizing online learning experiences.

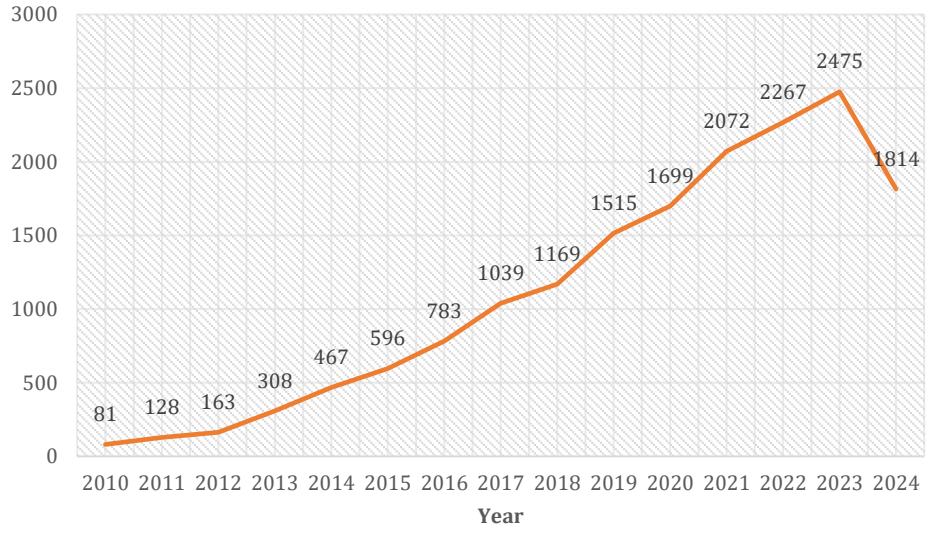


Fig. 2. Trends in Educational Data Mining Publications

Fig. 2 shows a significant upward trend in values from 2010 to 2023, with the highest peak reached in 2023, at around 2,475. However, further analysis reveals a drop in value in 2024. Although the year is not entirely over, the apparent decline could result from several factors that must be examined. Firstly, seasonal fluctuations may play a role in this decline. Some types of data often experience changes in value according to seasonal patterns, where specific values are higher at the end of the year due to the holiday season or other seasonal factors. In this context, the decline in early 2024 could be part of a pre-existing seasonal pattern.

Secondly, unforeseen events such as natural disasters, changes in government policies, or global crises can cause a deep drop in value. If such events occur as early as 2024, this could explain the decline observed in the chart. Thirdly, it is essential to consider possible changes in the long-term trend. Despite significant gains in recent years, fundamental factors in the economic or social environment may change, ultimately affecting the direction of the trend. Finally, data limitations are also a crucial factor. As the data for 2024 is incomplete, the decline seen today may be temporary and could change as more information becomes available.

Therefore, it is essential to exercise caution when interpreting the 2024 data. Unfinalized data is potentially misleading, and many external factors, such as global economic conditions and government policies, can affect the analysis results. In addition, understanding the context behind the data depicted is essential to avoid hasty conclusions. Overall, this chart's decline in value by 2024 needs to be analyzed with caution. Factors such as seasonality, unexpected events, trend changes, and data limitations should be considered. Further analysis is required to gain a more in-depth understanding, considering additional data and other relevant factors.

B. Visualization of Researcher Networks in Educational Data Mining

In addition, the analysis also shows a strong pattern of international collaboration in EDM research. Many publications involve authors from different countries and institutions, creating synergies in research that encourage the exchange of ideas and best practices. This collaboration not only broadens the scope of the study but also improves the quality and relevance of the results produced. This research also reflects how EDM is becoming a cross-disciplinary research topic, combining fields such as information technology, education, and psychology.

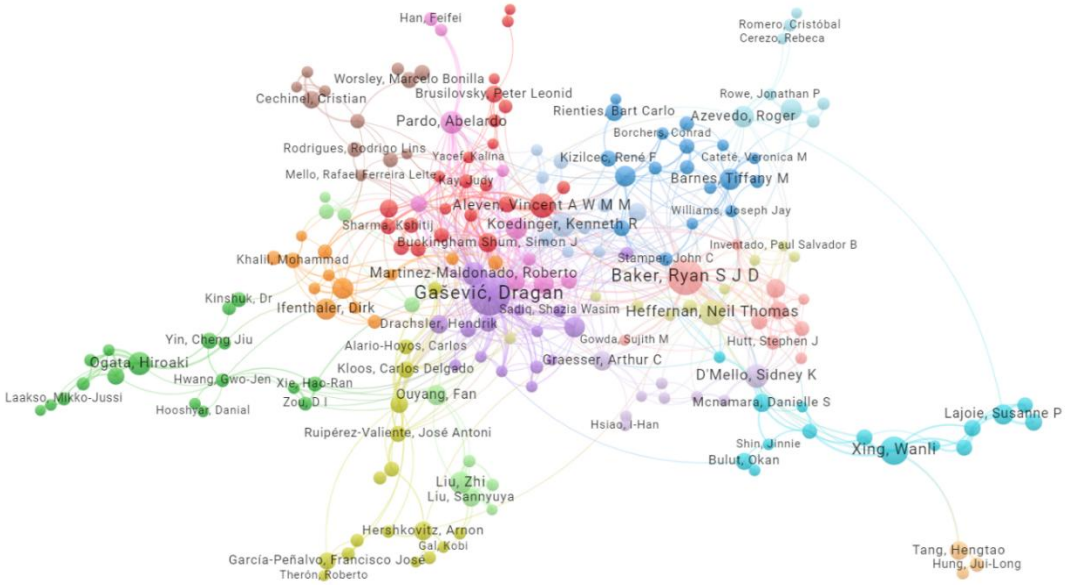


Fig. 3. Visualization of Researcher Networks in Educational Data Mining

In the network visualization (Fig. 3), the relationship between several researchers in a particular field may be related to learning or educational technology. Each node on the graph represents a researcher, while the lines connecting these nodes indicate collaborations or research links. One visible example is the relationship between Ryan S J D Baker and Dragan Gašević. The data shows that Dragan Gašević is the more productive researcher with 104 publications, compared to Ryan S J D Baker, who has 16 publications. Not only is productivity prominent, but Dragan Gašević is also more influential in the field, with 1939 citations compared to the 918 citations received by Ryan S J D Baker's publications. The high number of citations indicates that Dragan Gašević's works are more frequently referred to by other researchers, significantly influencing the academic community.

In addition, the network visualization shows connections between these two researchers, indicating a possible research collaboration or a common interest in the research topic. This shows that they are both involved in studies of high relevance in the field, although Dragan Gašević appears to have the upper hand in scientific productivity and influence.

Based on this data, it can be concluded that Dragan Gašević is a highly productive and influential researcher in the field. At the same time, Ryan S J D Baker is also active, although not as productive or influential as Gašević.

C. Global Research Distribution by Country

Fig. 4 provides an overview of the distribution of research by country, considering the number of researchers and total publications generated from each country. The United States significantly dominates, with 18 researchers who have produced 68 publications, reflecting its leading role in contributing to global research.

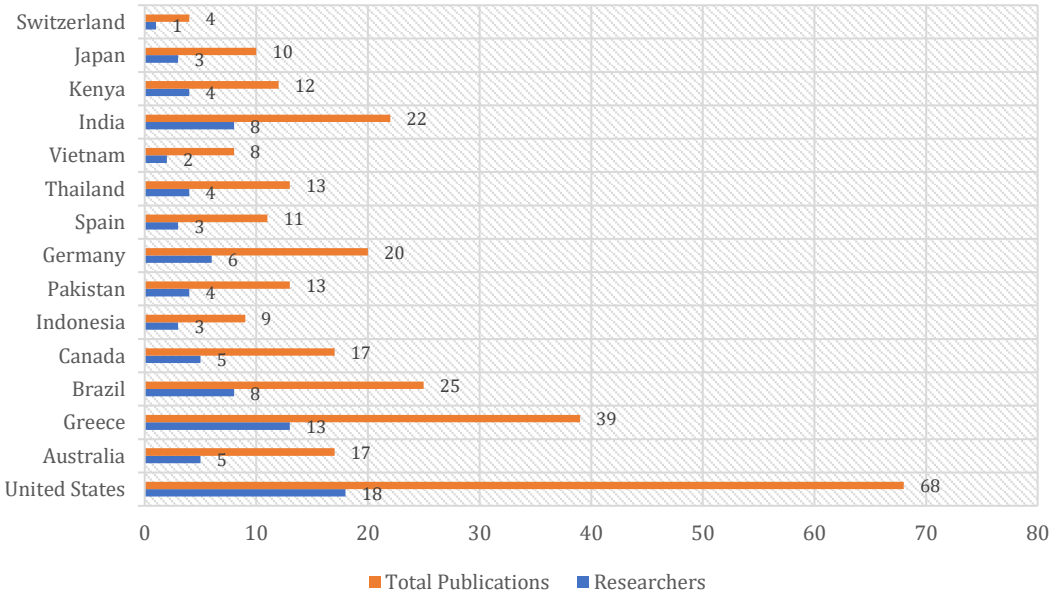


Fig. 4. Visualization of the Number of Publications based on Country

The many researchers and high publications in the US show that the country is one of the leading centers of research and innovation, particularly in technology and education-related fields. Australia and Canada, each with five researchers, have sizable contributions despite their smaller size than the US. Australia recorded 17 publications, while Canada produced the same number of 17 publications. This shows that despite the smaller number of researchers involved, they can significantly impact the international research community. Greece stands out as one of the European countries with a relatively large number of researchers (13) who produced 39 publications. This substantial contribution shows that Greece has a fairly productive research community. Brazil, with eight researchers producing 25 publications, also indicates a significant contribution, given that it belongs to a group of developing countries that are increasingly active in scientific research.

Countries such as Germany (6 researchers, 20 publications), Pakistan (4 researchers, 13 publications), and Thailand (4 researchers, 13 publications) demonstrate the ability to

compete in the international arena despite having fewer researchers. With its significant contribution to education and technology, Germany remains an essential European force. Meanwhile, as developing countries, Pakistan and Thailand show a substantial increase in research activity in the Asian region. With three researchers producing nine publications, Indonesia shows a growing involvement in global research. However, this figure suggests that Indonesia still has considerable room for improvement in the future. India, with eight researchers and 22 publications, and Kenya (4 researchers, 12 publications), also provide evidence that these countries continue improving their contribution to scientific research. Interestingly, although Vietnam only has two researchers, the country produced eight publications, which shows a relatively high productivity compared to the number of researchers. On the other hand, with three researchers producing 10 publications, Japan continues to show consistency as a country with a strong reputation in technological innovation and education. Meanwhile, although Switzerland only has one researcher in this data, the country still produced four publications. This shows that even with a few researchers, the quality of research from Switzerland is maintained, confirming their reputation as a center of innovation and academic excellence.

This data clearly shows how different countries contribute to global research. Countries such as the United States and Greece are at the forefront. In contrast, developing countries such as Indonesia, Pakistan, and Kenya continue strengthening their position in the international research community. This analysis emphasizes the importance of cross-border research and shows that while the number of researchers varies by country, their impact on academia remains significant.

D. Implications for Transformational Leadership

Research involving EDM is essential to supporting transformational leadership practices in education [15]. In this context, leading researchers such as Ryan S. J. D. Baker and Dragan Gašević have shown how educational technology and learning analytics can be instrumental in improving the quality of education [16]. By using data to understand students' learning patterns, they emphasize that utilizing analytic insights can improve teaching effectiveness [17] and provide a deeper understanding of the needs and challenges students face in the learning process [18]. The role of transformational leaders is particularly relevant in this context, as they act as change agents who are not only able to inspire staff and teachers [23] but also encourage them to continue to innovate [19] and make continuous improvements [24]. Leaders who adopt this approach will better create a dynamic learning environment [20], where teachers and students feel supported to explore new methods and innovative ideas [21]. By utilizing insights from EDM, educational leaders can design strategies that are more adaptive to student needs [22]. For example, through in-depth data analysis[23], they can

identify student success patterns and challenges, thus enabling more responsive and relevant curriculum development. Furthermore, implementing EDM principles in the context of educational leadership creates an environment that encourages innovation and supports data-driven learning [24]. In this regard, transformational leaders are managers and pioneers who integrate technology and analytics into strategic decision-making [25]. This strengthens the achievement of common goals [26], both in improving the quality of education and in developing students' characters that are adaptive to changing times [27].

The implications of using EDM in educational leadership emphasize the importance of leadership that is not only responsive to current challenges, but also [28], but also proactive in implementing sustainable and future-oriented policies [29]. Educational leaders who can integrate data and analytics into their practice will be better equipped to face global challenges in education, create inclusive learning environments, and ensure that all students can reach their full potential in an ever-evolving educational ecosystem [30].

Conclusion

The conclusions drawn from this study indicate that research on EDM has not only experienced rapid development but also has a significant impact on transformational leadership practices in education. The analysis reveals strong patterns of international collaboration, where researchers from various countries and institutions work together to create synergies that enrich research through exchanging ideas and best practices. This contributes to enhancing the quality and relevance of research outcomes, fostering cross-disciplinary perspectives that integrate information technology, education, and psychology. Regarding collaboration, network visualization illustrates the relationships between researchers such as Ryan S. J. D. Baker and Dragan Gašević, highlighting their interconnectedness in research and showing differences in productivity and influence. Dragan Gašević, with more publications and citations, signifies a substantial impact within the academic community. At the same time, Ryan S. J. D. Baker remains active despite being less prolific than Gašević. Furthermore, the distribution of research by country shows the United States as a dominant center for research and innovation, followed by significant contributions from countries like Australia, Canada, and Greece. Emerging countries such as Indonesia, Pakistan, and Kenya also show increased research activity, creating hope for sustainable growth in the future.

The implications of EDM for transformational leadership emphasize the importance of leaders who can integrate data-driven insights into their practices. Educational leaders who can utilize analytics to understand student learning patterns will be more effective in designing responsive strategies that support innovation in learning environments. Thus, this research

aims to deepen the understanding of the importance of EDM and its role in enhancing educational quality and fostering sustainable and adaptive leadership development in response to changing times.

Conflict of Interest

The authors declare that there is no conflict of interest.

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