REVIEW OPEN ACCESS

Enhancing Student Outcomes through Big Data in Learning Management Systems: A Scoping Review

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Abstract

As digital learning platforms continue to grow at an unprecedented pace, big data technologies are becoming an integral part of Learning Management Systems (LMS). However, the impact of big data on improving LMS to achieve positive student outcomes remains uncertain, necessitating the need for a thorough review. The objective of this scoping review is to examine how big data technologies are applied within LMS and assess their impact on improving student outcomes, focusing on key themes such as predictive analytics, machine learning applications, and the optimization of learning paths. A systematic search was conducted across two databases, identifying ten peer-reviewed studies published between 2015 and 2024. These studies were analyzed to explore the various methods and frameworks used in LMS that incorporate big data analytics. Studies were selected based on relevance to big data and its application in educational settings, particularly LMS. The findings demonstrate that big data significantly contributes to improving student outcomes by enabling predictive analytics for student performance, personalized learning through Educational Data Mining (EDM), and enhancing decision-making in educational management. The reviewed studies also highlight challenges, such as data privacy issues and infrastructure limitations. In conclusion, big data technologies hold substantial promise for transforming LMS and advancing personalized education. However, more research is needed to address challenges and optimize the use of big data for sustained improvements in educational outcomes.

Keywords: Big Data, Learning Management Systems (LMS), predictive analytics, educational data mining, machine learning in education.

1. INTRODUCTION

Artificial intelligence (AI) technology is being applied increasingly to advance workplace tasks, enhance learning, and provide teachers and students with real-time feedback [1]. Instruction, assessment, and learning management have grown as an outcome of using artificial intelligence (AI) in educational domains [2]. AI in education predicts progress toward learning environments that are more flexible, data-driven, and effective [3]. A good example of this kind of achievement is the adoption and use of learning management systems (LMS), which currently use AI to greatly improve learning outcomes.

The implementation of AI to assess various LMS has caused major changes to the current education [4]. Artificial intelligence (AI) algorithms can analyze huge amounts of data from learning management systems (LMS) to identify patterns and trends in student behavior, engagement, and academic achievement.

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By improving lesson plans based on different student learning styles, teachers can eventually enhance overall learning outcomes [5]. According to Mutambik [6], precise options, automatic evaluation, and individual paths to learning are included in an AI-powered learning management system. While ensuring that students receive accurate and timely evaluations, these features reduce the workload of teachers as well.

It has been demonstrated that student outcomes can be significantly improved via learning with advancements in artificial intelligence (AI) and data analytics [7]. Students can achieve several goals, including performance based on factors such as participation and retention rates, as well as other areas of interest to the organization. Specifically, the behavioral, emotional, and intellectual areas are addressed by these parts. Remember that skills and knowledge are cognitive results, motivation, and attitudes are psychological outcomes, and social growth effects result from commitment to learning activities or participating in them [8].

Educators may fast identify students' domains of strength and weakness, and use focused Instructional strategies to

Table 1: Eligibility criteria for article selection.

Eligibility Criteria	Inclusion Criteria	Exclusion Criteria
Title	• Articles published from January 2019 to January 2024. • English Articles	• Articles in languages other than English. • Articles and studies published before 2019.
Abstract	• Abstract reflects an original article • Abstract provides a study design (qual itative and quantitative). • Abstract provides evidence of evaluation of online learning environments	• Research conducted on secondary and primary education • Research on higher education which does not focus on medical undergraduate education
Full text	• Studies that specifically explore the i mpact of big data analysis on Learnin g Management Systems (LMS) and st udent outcomes.	• Articles from non-academic blogs, opinion articles, editorials, and other non-peer-reviewed sources. • Research that does not examine AI applications in the context of learning management systems.

enhance their educational performance using the LMS's comprehensive understanding of these outcomes, as is received through big data analytics [9]. Whilst integrating AI and big data analysis with LMS may provide advantages, there are still many issues to be addressed and knowledge gaps to be filled [10].

This review aims to investigate how big data analysis can be used in learning management system to improve performance in learners. Until now, there has been a lack of research on school-based big data and AI in education to home management systems (LMS) as well as student results.

The objective of this scoping review is to address the knowledge gap by gathering together existing papers and distilling key themes, findings, and issues helping identify research gaps to establish a framework for future studies in this area.

2. METHODOLOGY

2.1. Identification of Research Question

The review aimed to answer one main research question, "How does big data analysis impact learning management systems for better student outcomes?" For review purposes, an operational definition of big data analysis was defined as "processes involving using descriptive, analytical, and prescriptive analytics on student engagement, performance, and behavioral data". The population was identified to be medical college students, the concepts were big data, Learning Management Systems (LMS), and student outcomes.

2.2. Finding Appropriate Studies

Original, peer-reviewed research papers published between January 2019 and January 2024 were found after a literature search. Two electronic **[DATABASE UPDATED]** databases PubMed and Google Scholar were used for the literature search. Following an exploratory search, the first set of keywords had been filtered to include Big Data Analysis AND Medical Education OR Learning Management Systems (LMS).

2.3. Study Selection

Articles obtained from the two databases were evaluated based on eligibility criteria for full text, title, and abstract article selection to ensure robustness in article selection. The articles were chosen using predetermined eligibility criteria based on the title, abstract, and full-text screening (Table **1**). The process for article selection criteria, encompassing title, abstract, and full-text screening, are outlined in Fig. (**1**).

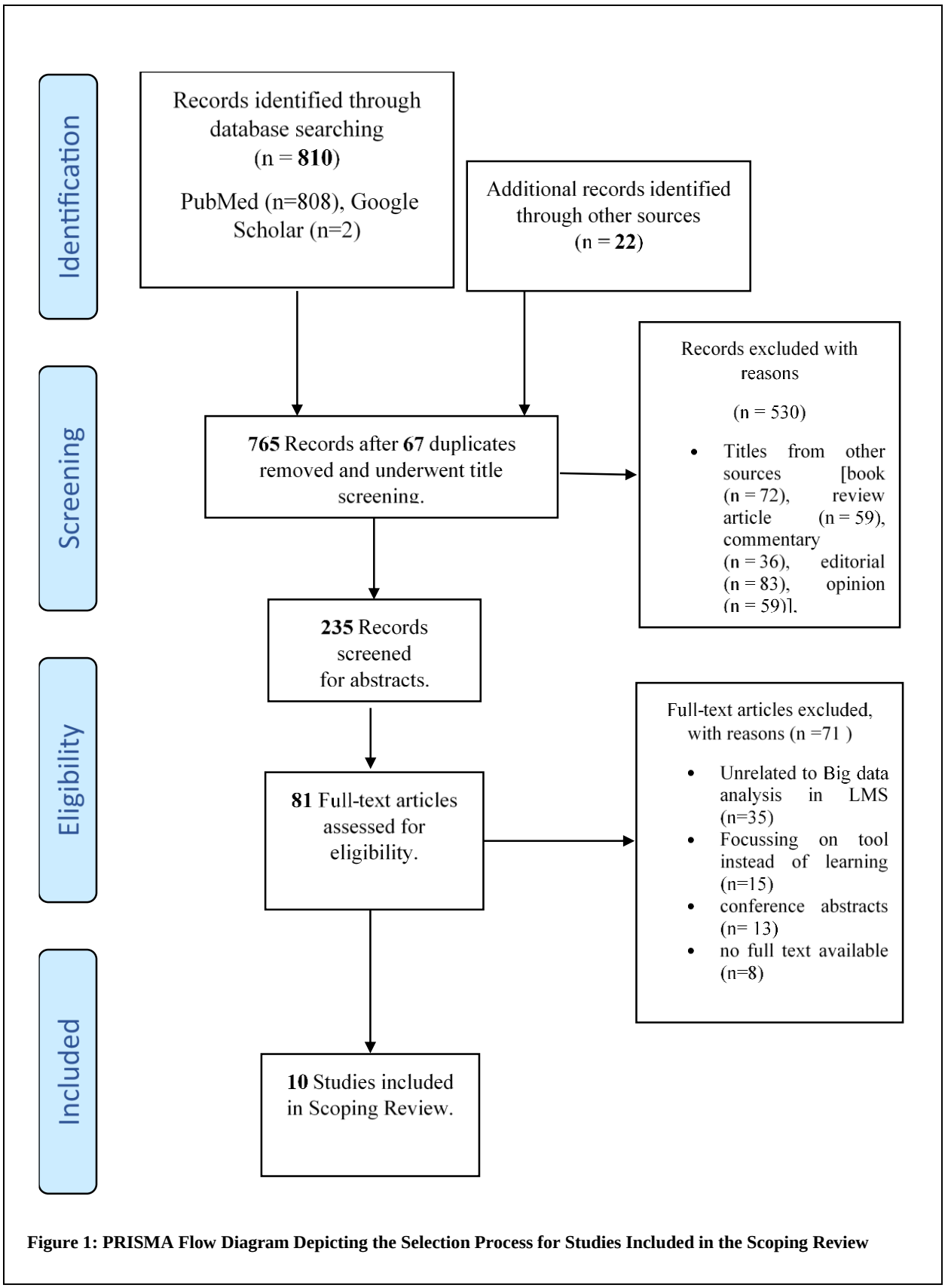

Figure 1: PRISMA Flow Diagram Depicting the Selection Process for Studies Included in the Scoping Review

2.4. Data Charting

An unbiased review summary was produced by reviewing the final chosen papers and extracting their data into an Excel sheet. The extracted data was arranged based on the following categories such as (i) author (ii) article title (iii) year of publication (iv) study purpose/objective (v) research design & Methods (vi) data collecting tool (vii) study population (viii) study conclusion.

2.5. Collecting Data, Summarizing, and Reporting the Findings

Microsoft Excel was used to analyze the content of an independent researchers (SZ+ NKN). While the thematic analysis focused on developing concepts associated with big data analysis in learning management system, the initial phases of content analysis allowed the researcher to gain a deep understanding of the functional parts of the latter. The researchers classified the developing primary themes into themes and subthemes and characterized them during the thematic analysis process. After reaching an agreement, the developed themes and subthemes were finally examined and finalized.

2.6. Consultation

A medical education expert was consulted during the article selection process before it was reviewed. Furthermore, the theme analysis data was triangulated by experts in qualitative research methodologies, facilitating a finalization review of the list of open, axial, and selective coding.

3. RESULTS

3.1. Study Characteristics

The selected 10 studies were published between January 2015 to July 2024 with publications from various countries mentioned in Table **2**.

This scoping review explored the integration of big data into learning management systems (LMS), its impact on student performance and outcomes, and the technological applications and challenges faced in educational settings. The review identified some key themes and sub-themes from the literature, as given below in Table **3**.

3.2. Theme 1: Big Data and Learning Management Systems (LMS)

Big data technology integration in education learning management systems (LMS) has been a significant field of research mostly as it relates to enhancing the capacity of educational institutions to manage and evaluate huge amounts of student data.

Sethy and Panda [11] demonstrated that big data technologies like Hadoop and map-reduce technologies have become essential for processing huge amounts of educational data. Based on their research study, "*educational institutions can better study students' performance and focus on their weak areas by using map-reduce techniques and a Hadoop cluster for efficient processing of large amounts of student data*".

Further, machine learning algorithms have been used to predict student outcomes by analyzing LMS trace data. According to Umer *et al*. (2019), "*By examining LMS trace data and assessment scores, the study utilized machine learning algorithms to predict students' outcomes in a course*."

The goal of these studies was to build adaptive learning environments through the optimization of learning courses within learning management systems (LMS) through mathematical models. Levin *et al*. (2023) proposed along with a mathematical model for managing the learning trajectory in the 'Big Data LMS' module in order to build an adaptive learning management system at the university.

Table 2: Characteristics of the selected studies in this scoping review (n=10).

Feature	Discipline	Number
Year of Publication	2015-2018	1
	2019	2
	2020	2
	2021	0
	2022	4
	2023	1
	2024	0
Country of Publication	China	3
	Russia	2
	Australia	1
	Ecuador	1
	India	1
	Muscat	1
	Saudi Arabia	1

3.3. Theme 2: Student Performance and Outcomes

Big data analytics has been instrumental in predicting and improving student performance, personalizing learning, and monitoring student engagement.

Table 3: Identified themes and sub-themes from the scoping review.

Theme	Sub-Theme	Reference
Big Data and Learning Management Systems	Integration of Big Data Technologies	[11, 12]
	Application of Machine Learning Algorithms	[13, 14]
	Optimization of Learning Trajectories	[12, 14]
Student Performance and Outcomes	Predictive Analytics for Student Performance	[13, 14]
	Monitoring Student Attention Levels	[15]
	Educational Data Mining (EDM) for Personalized Learning	[16, 17]
Impact on Teaching and Learning Processes	Enhancing Teaching Quality and Decision-Making	[18, 19]
	Adapting Educational Content	[17, 20]
	Creating Personalized Educational Models	[16, 20]
Technological Implementation and Infrastructure	Development of Automation Systems	[11, 21]
	Use of IoT and Sensing Devices	[15]
	Python-Based Systems for Educational Data Mining	[17]
Challenges and Countermeasures	Identifying and Addressing Issues in Educational Management	[18, 19]
	Optimization Strategies	[12, 19]

By using big data, predictive analytics can predict student performance and provide meaningful information that can be used to enhance learning outcomes [13]. Boughouas *et al*. (2022) demonstrated the application of machine learning techniques to an educational dataset in predicting student performance and providing recommendations to improve student outcomes.

Apart from predicting student outcomes, applying big data and sensing technologies to track the involvement of students has provided insightful information about attention spans in learning environments. Study done by Muhsin *et al*. (2020) demonstrated that using sensing devices to observe attention levels of the students can help monitor the students in online platforms [15].

Studies have noted that quick access to student data is crucial to individualized learning. Research by Kotova (2019) highlighted the need to have immediate access to data regarding students' mental and cognitive activity to modify lessons, lessen cognitive overload, and enhance the learning process [16].

3.4. Theme 3: Impact on Teaching and Learning Processes

The use of big data in education has led to significant enhancements in teaching quality, decision-making processes, and the development of adapted educational models.

Research shows that the use of big data can enhance decision-making and the quality of teaching by offering improved educational management tools. Big data has greatly enhanced China's university education management, resulting in increases in teaching quality and a better

learning and working environment for educators and students [19].

Analytics of educational data provide efficient administration of the learning process with content adaptation to meet the goals of specific students. Kotova (2019) analyzed the utilization of AI to modify instructional content and lessen the cognitive load. This is accomplished by gathering information about the unique characteristics of students' cognitive and mental activity.

Big data makes it easier to create customized models of learning, which facilitates adaptive learning. Sethy and Panda (2015) recommend the use of big data architecture for educational data analysis to meet students' individual needs to create personalized educational models that promote adaptive learning in a university setting.

3.5. Theme 4: Technological Implementation and Infrastructure

The development and implementation of technology for educational purposes have been explored, focusing on automation systems, Internet of Things (IoT), and educational data mining tools. For better educational administration platforms, automation solutions built on big data analytics are being developed. This has been demonstrated by Huizhong *et al*. (2022) via development of an automation integration terminal based on big data analysis for the education management platform.

The potential for predictive abilities provided by IoT and sensing devices in education has been examined in research. The potential of contemporary technologies like big data and the Internet of Things to provide higher education institutions with preemptive and predictive capabilities, help administrators make better decisions, and support teachers in enhancing their instructional strategies [15].

Furthermore, frameworks for analyzing educational data are provided by Python-based systems that have been developed for educational data mining. Study by Wang *et al*. [17] presents a basic framework and procedure for educational data mining and analysis in the field of education.

3.6. Theme 5: Challenges and Countermeasures

Despite the advantages of big data in education, challenges persist thus requiring the development of optimization strategies to address them. Many issues with educational management have been noticed, and optimization solutions are therefore required. According to Zhoa *et al*. (2022), there are still challenges and problems in the educational management of some universities in China, necessitating the development of optimization countermeasures to address these issues, despite the positive impact of big data.

On the other hand, Huizhong *et al*. (2022) focused on developing precise frameworks and methods to deal with these issues. "The proposed framework in the paper achieves an accuracy of 99.1% in simulation analysis, demonstrating high reliability in assessing student communication and curriculum quality compared to existing methods," according to a study that offered a trustworthy framework [21].

4. DISCUSSION

The outcomes of this scoping review emphasize how big data analysis in Learning Management Systems (LMS) can revolutionize teaching and learning, especially when it comes to improving educational techniques through personalized learning, predictive analytics, and adaptive learning environments. Learning management systems (LMS) that use technologies for big data have been shown to significantly boost by allowing educational institutions to use huge amounts of data to make well-informed decisions and adapt learning experiences based on the demands of each student [3].

4.1. Big Data and Learning Management Systems (LMS)

Integrated learning management systems (LMS) and big data systems offer an effective structure for organizing and analyzing big data sets, as multiple studies have shown, enabling a greater comprehension of student performance and learning patterns [4].

According to Sethy and Panda (2015), map-reduce techniques and Hadoop clusters are discussed as tools for effectively controlling huge amounts of student data. Teachers may use this data to determine areas where students may require further assistance. This is consistent with other research findings that showed how big data may optimize how students learn and allow learning management systems (LMS) to adapt to the particular requirements of each student [22].

As mentioned by Umer *et al.* (2019), "*integrating machine learning algorithms into LMSs can assist in the predictive modeling of student outcomes*." These algorithms analyze LMS trace data and assessment results to forecast student performance. This, in turn, enables educators to provide personalized real-time feedback to learners. Learning Analytics Dashboards (LAD) are more effective in this regard as they consolidate data from various sources to offer a comprehensive view of student learning success [23, 24].

4.2. Impact on Teaching and Learning Processes

The results presented align with a larger set of work that shows big data can improve grading systems by allowing data-driven, objective assessments and reducing manual errors, which will result in better grading systems. Big data has significantly enhanced teaching quality in China's university education management enhancing the learning environment for students and teachers [19].

In addition, the adaptable nature of Learning Management Systems (LMS) needs a modification of teaching methods

and educational materials to different styles of learning [12]. This flexibility enables learners to remain driven and involved while also effectively managing cognitive work; this can be determined with educational data mining (EDM) techniques. Big data plays a vital part in developing efficient and individual learning environments, and the literature continues to discuss the potential of adapting learning experiences based on individual student data [14].

4.3. Technological Implementation and Infrastructure

The use of big data technologies in educational settings has been a field of research, especially in the areas of automation system development, Internet of things use and sensing device use. This review demonstrated the potential of these technologies in speeding educational processes and improving decision-making, for example, by discussing the development of an automation integration terminal for educational institution platforms based on big data analysis [21].

In addition, the integration of IoT and sensing devices augment the capacities of academic establishments by providing rapid information on learner involvement and attention. This is consistent with a greater amount of research that supports the effective monitoring and modification of teaching tactics through the use of real-time dashboards and predictive modeling [15]. These technological developments are necessary to address the different needs of students by promoting an educational environment that is more dynamic and adaptive.

4.4. Challenges and Countermeasures

Considering all of the advantages of implementing big data into LMS, there are still certain challenges that must be resolved. Optimization measures are necessary since, as highlighted by Zhao *et al.* (2022), there are still problems with the way some colleges, especially in China, handle their curricula. This result is in line with the larger body of literature that recognizes the difficulties posed by big data, including issues with data privacy, the intricacy of data integration, and the requirement for a strong infrastructure to enable large-scale data processing.

Several researches have suggested optimization techniques and frameworks that show high reliability in evaluating educational processes to address these issues [12, 25]. These techniques guarantee that big data integration into educational settings is sustainable and successful in addition to helping to overcome the barriers.

This review was limited by a small number of selected studies. In light of the most current research, this scoping study emphasizes the important part that big data plays in enhancing teaching methods. The focus on real-time feedback systems, predictive analytics, and personalized instruction fits in with previous studies that show the importance of data-driven instructional techniques. Learning management system (LMS) integration with big data analysis is a major development in the field of education, providing the resources required to develop personalized, flexible, and effective learning environments.

There is a need to address issues, such as infrastructure needs, privacy, and cost-effective implementation of new technologies if we are to effectively take advantage of it. Therefore, using big data technologies used by educational institutions, future studies can be directed towards development of new frameworks and innovative methods to overcome challenges and build on the promise of educational analytics. The findings of the evaluation can serve as a solid foundation for future research and lead the development of academic communities to enhance students' personalized learning environments.

5. CONCLUSION

In this scoping review, we examine how big data analytics can improve current teaching methods and transform learning management systems (LMS). By integrating data with LMS, we can enhance learning objectives, standards, and student achievement, resulting in personalized learning environment for each student. Predictive analytics, instructional data mining, and real-time feedback systems can facilitate this transformation. However, some limitations prevent these learning advantages from reaching their full potential.

We have to address several issues, such as infrastructure needs, privacy, and cost-effective implementation of new technologies if we are to appropriately take advantage of it. Therefore, while using big data technologies found in educational institutions, it is vital to develop new frameworks and innovative methods to overcome challenges and build on the promise of educational analytics. These findings will serve as a solid ground for future research and guide the development of academic communities to improve students' personalized learning environments.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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AUTHOR'S CONTRIBUTIONS

SZ: Did the initial literature search , data charting , analysis and initial manuscript writing.

NN: Conceived the idea, did literature search, data charting, analysis and final manuscript writing.

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