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Review Article

Benefits and Challenges of Using Learning Analytics in Medical Education: A Scoping Review

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ABSTRACT

Background: Learning analytics includes collecting and analysing learners' data to improve and personalize the learning process. In medical education, its potential value is significant because learning outcomes directly impact patient care. Whereas, research in this field remains scattered. Therefore, this scoping review aimed to map existing literature on the use of learning analytics in medical education, focusing on its definitions, applications, benefits, and challenges, to identify evidence gaps and guide future research and practice.

Methods: Following the Arksey and O'Malley scoping review framework and guided by the PRISMA-ScR checklist, a scoping review of publications addressing learning analytics in medical education was conducted. Relevant literature was identified through searches of international databases, including Scopus, PubMed, Web of Science (WOS), and Education Resources Information Center (ERIC). Searches used predefined keywords and were limited to English-language publications published between 2010 and 2024. Eligible studies included empirical and review articles within all academic levels in medical education context. Two reviewers independently screened and charted the data, and results were synthesized thematically across key domains.

Results: Initially, a total of 2,056 articles were identified. During the first screening stage, studies were filtered based on the relevance of their titles and abstracts, resulting in 196 articles advancing to the second phase. After a thorough full-text review, 20 articles that met all inclusion criteria were finally selected for analysis. The extracted findings were categorized into four main themes: definitions, applications and advantages, disadvantages and challenges, and general information on learning analytics.

Conclusion: Learning analytics offers considerable potential to enhance medical education through personalized learning, better decision-making, and improved outcomes for learners and patients. Yet, its adoption remains limited and fragmented, with challenges including ethical concerns, technical barriers, and the lack of standardized frameworks. Future research should develop standardized frameworks, address ethical and technical issues, and evaluate impacts on learner outcomes and patient care. Current evidence may be biased due to publication and language limitations; future research should include non-English sources and larger, more diverse datasets to enhance validity and generalizability.

Keywords: Learning Analytics, Medical, Education, Learning; Educational Technology

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Introduction

Educational informatics is a multidisciplinary field that applies Information and Communication Technology (ICT) to education and training. Within this field, analytics has emerged as a powerful approach for improving decision-making. Analytics can be categorized across three dimensions—time, level, and stakeholders—and applied using descriptive, real-time, and predictive methods to monitor processes, forecast outcomes, and support evidence-based decisions (1-6). These approaches operate at different levels, from the "nano-level" (specific activities within a module) to the "macro-level" (institutional curricula) (7, 8). At higher levels, the term *academic analytics* is often used, emphasizing decision-making related to pedagogy, management, and program design (9).

Building on this foundation, learning analytics has emerged as a subfield that focuses specifically on education. It is defined by the Society for Learning Analytics Research (SoLAR) as *"the measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs* (10)*."* Learning analytics employs statistical and computational methods to describe and predict learning behaviors, offering valuable feedback to both learners and instructors. This feedback can support personalized instruction, performance monitoring, and continuous improvement in educational systems (11, 12). Over the past decade, the expansion of online learning has further accelerated interest in learning analytics as an essential component of technology-enhanced learning (13, 14).

Many industries, including finance, sports, and security, have already leveraged analytics successfully. In contrast, medicine has been slower to adopt such approaches, with most applications focused on clinical quality improvement rather than education (15). Within medical education, systematic applications of learning analytics remain sparse. Existing examples—such as the McMaster Modular Assessment Program for Medical Emergencies (16-18), online modules for X-ray interpretation (19, 20), and the Internal Medicine Program Analysis Dashboard (21)—illustrate its potential but remain isolated efforts.

Despite growing recognition of the value of learning analytics, there is no comprehensive review that classifies its definition, applications, benefits, and challenges in medical education. Previous reviews have primarily addressed learning analytics in broader higher education contexts (22, 23), but to our knowledge, no study has systematically mapped this field in relation to medical education. This gap limits the ability of educators, administrators, and policymakers to fully understand the scope of learning analytics in this domain and to identify opportunities for its effective implementation.

Therefore, this study conducted a scoping review to consolidate existing evidence, identify applications, and classify the advantages and limitations of learning analytics in medical education. By organizing current knowledge in a structured manner, this review aimed to provide a foundation for future research and practical adoption in the field.

Methods

Study Design

This study was conducted following the Arksey and Omalley scoping review framework (24) and in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Extension for Scoping Reviews (PRISMA-ScR) checklist (25). Scoping review approach was selected to systematically map the breadth and extent of research related to learning analytics in medical education. The review process followed the five-stage framework for scoping reviews proposed by Arksey and O'Malley, which comprises formulating the research question, identifying relevant studies, selecting eligible studies, charting the data, and collating, summarizing, and reporting the findings. The central research question guiding this review was: "What is learning analytics in medical education and its application?" Relevant studies addressing this question were identified and analyzed according to the defined inclusion criteria.

Search Strategy

A comprehensive literature search was conducted in four databases: Scopus, PubMed, Web of Science (WOS), and Education Resources Information Center (ERIC). The search strategy combined MeSH terms and free-text keywords related to learning analytics and medical education:

• "Learning analytic*" OR "learning analytics"

• Medical education OR Education, Medical

The search strategy based on the selected keywords was as follows:

("learning analytic*" AND ("medical education" OR (education AND medical))

The search strategy was tailored to each database: in PubMed, MeSH terms (e.g., Education, Medical) were combined with free-text keywords (e.g., 'learning analytics'), while in Scopus, WOS, and ERIC, equivalent keyword-based strategies were applied according to their indexing formats.

The search was limited to publications from the beginning of 2010 to October 2024, as learning analytics formally emerged as a research field following the first Learning Analytics and Knowledge (LAK) conference in 2011 (23). Restricting to this timeframe ensured inclusion of studies conducted within the period when learning analytics gained global academic attention. Moreover, both primary studies and review articles were included to ensure comprehensive coverage of existing evidence, capture synthesized insights, and identify gaps in the literature related to learning analytics in medical education.

Selection Criteria

The studies were included if they involved a clearly defined population and focused on the use of learning analytics in medical education, including undergraduate, postgraduate, or continuing medical education contexts. Eligible study types encompassed both primary research (quantitative, qualitative, or mixed-methods) and secondary research, such as systematic, scoping, or narrative reviews. In addition, only studies with full-text availability and written in English were considered for inclusion.

Studies were excluded if the full text was unavailable, the article was not published in English, or the focus was outside the context of medical education. Commentaries, books, and letters were also excluded, as well as grey literature, including theses and conference abstracts. Duplicate or overlapping reports of the same study were removed from the review.

All retrieved records were imported into EndNote, where duplicates were removed through both automated and manual processes. Two reviewers independently performed the screening of the titles and abstracts, which followed by independent full- text assessment. A total of 2056 resources were retrieved. It reached 1879 after removing 177 duplicate resources. In the first stage, the title and abstracts of the articles were reviewed to determine the relevance of the papers. Full texts of the papers that were eligible for inclusion in the study were reviewed in the next step. In the first stage, 1683 articles were excluded from the study because they did not meet the inclusion criteria. As a result, 196 articles entered the second phase of review. In the second stage of the study, the full text of 196 articles that were eligible for inclusion was reviewed, of which 176 articles were excluded because they did not meet the inclusion criteria. Finally, 20 articles that met all the inclusion criteria were included in the study.

Data Extraction

Using a data charting form, key information from each included study was extracted, and the following variables were recorded: the author(s), year, and country; study type and design; educational level (undergraduate, postgraduate, or continuing); purpose and definition of learning analytics; data sources and analytic methods; main findings and reported applications of learning analytics; and reported benefits, challenges, or recommendations.

After pilot testing of the three studies to ensure consistency, the data extraction was performed by two reviewers independently. Any disagreements were resolved through discussion until consensus was achieved.

Quality Assessment

A standard data extraction sheet was developed, and two independent reviewers extracted the information to ensure accuracy and reduce potential bias. Any discrepancies were resolved through discussion. The purpose of the synthesis was to map and describe the breadth of evidence, not to assess study quality or effectiveness. Accordingly, no formal critical appraisal or risk-of-bias assessment was conducted, consistent with scoping review methods.

Data Synthesis and Analysis

The extracted data were thematically synthesized using an iterative process. Descriptive numerical summaries (such as study type, year, and geographic distribution) were combined with qualitative thematic analysis to identify key areas such as definitions, applications, implementation strategies, benefits, challenges, and ethical considerations in learning analytics in medical education.

Results

Data charting was conducted as a descriptive–analytical approach using a standardized form to systematically collect and organize information derived from the literature search. All retrieved publications were screened and reviewed systematically according to the predefined inclusion and exclusion criteria, and the selection process was reported using the PRISMA-ScR flow diagram (Figure 1).

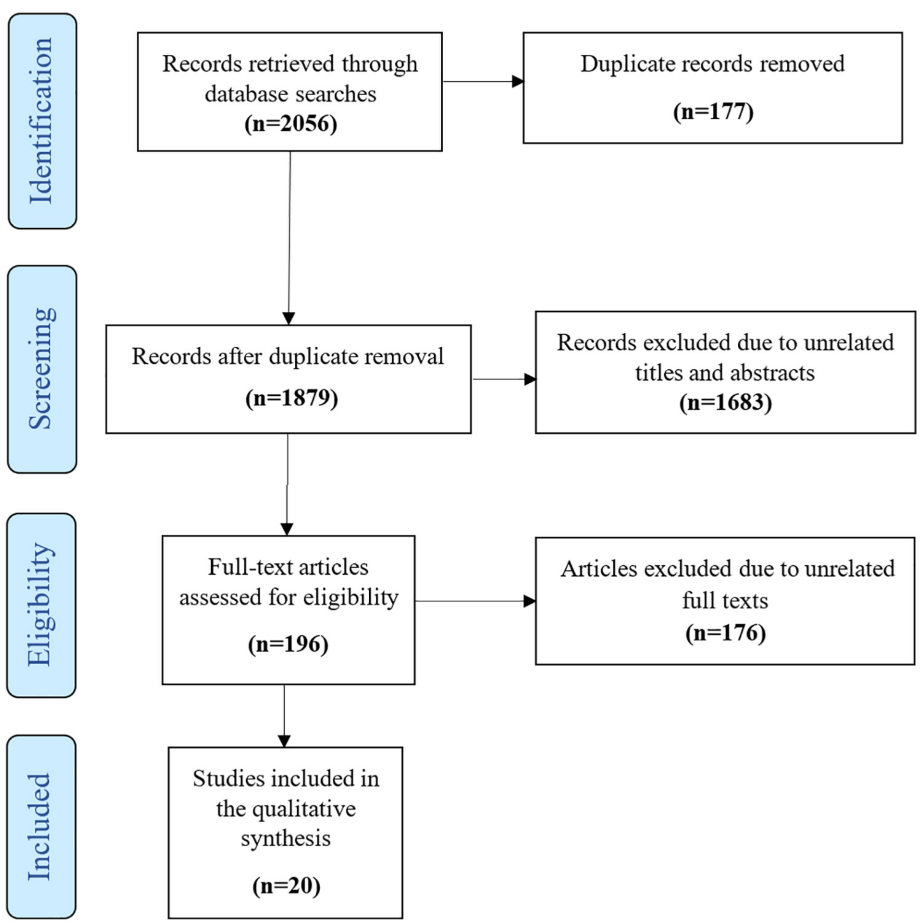

Figure 1: PRISMA flow diagram

As illustrated in Figure 1, a total of 20 articles that met the inclusion criteria were finally included in the review. Table 1 presents a summary of the extracted data, categorized by article title, year of publication, author, study design, and educational level.

According to Table 1 and Figure 2, the distribution of included studies between 2012 and 2023 shows an increasing trend over time, with the highest number of publications observed in 2020 and 2023 (four studies each). The noticeable rise in publications from 2016 onward reflects growing research interest in the topic in recent years.

According to Figure 3, the highest number of included studies were conducted in the United States (six studies), followed by Canada (four studies). Germany and Singapore each contributed two studies, while Greece, Saudi Arabia, Australia, Sweden, Italy, and Finland each accounted for one study. This distribution indicates that most research in this field has been carried out in North America and Europe.

Table 1: Bibliographic information of included articles

	Title	Authors	Year	Country	Study Design	Educational Level
1	Learning Analytics: A Case Study of The Process of Design of Visualizations	Olmos M. and colleagues	2012	Australia	Qualitative case study	Undergraduate
2	A Conceptual Analytics Model for an Outcome-Driven Quality Management Framework as Part of Professional Healthcare Education	Hervatis V. and colleagues	2015	Sweden	Deductive case Study	Professional training
3	Using Learning Analytics to Identify Medical Student Misconceptions in an Online Virtual Patient Environment	Poitras EG. and colleagues	2016	Canada	Observational empirical study (case-based analytics study)	Undergraduate
4	Process-Oriented e-Learning System for Training Healthcare Professionals on Big Data Usage	Karabetsou V. and colleagues	2016	Greece	Educational system development	Professional training
5	Introduction: Analytics Research and Case Studies in Online Learning	Vignare K. and colleagues	2016	USA	Narrative Editorial	Mixed
6	How Learning Analytics Can Early Predict Underachieving Students in A Blended Medical Education Course	Saqr M. and colleagues	2017	Saudi Arabia	Quantitative observational study	Undergraduate
7	The Flipped Classroom and Learning Analytics in Histology	Gilliland KO.	2017	USA	Educational case study	Undergraduate
8	A Big Data and Learning Analytics Approach to Process-Level Feedback in Cognitive Simulations	Pecaric M, and colleagues	2017	USA	Experimental simulation-based study	Graduate/ Residency
9	Learning Analytics in Medical Education Assessment: The Past, The Present, and The Future	Chan T. and colleagues	2018	Canada	Narrative review / conceptual analysis	Graduate/ Residency

	Title	Authors	Year	Country	Study Design	Educational Level
10	Click-Level Learning Analytics in An Online Medical Education Learning Platform	Matthew M. and colleagues	2020	USA	Observational analytics study	Undergraduate
11	Team-Based Learning Analytics: An Empirical Case Study	Koh YYJ. and colleagues	2020	Singapore	Empirical case study	Undergraduate
12	The Use of Learning Dashboards to Support Complex In-Class Pedagogical Scenarios in Medical Training: How Do They Influence Students' Cognitive Engagement?	De Leng B. and Pawelka F.	2020	Germany	Mixed-methods study	Undergraduate
13	Ten Caveats of Learning Analytics in Health Professions Education: A Consumer's Perspective	Ten Cate O. and colleagues	2020	Germany	Conceptual analysis / perspective	Mixed
14	Image Interpretation: Learning Analytics–Informed Education Opportunities	Thau E. and colleagues	2021	Canada	Prospective cross-sectional interpretation study	Undergraduate
15	From Utopia through Dystopia: Charting a Course for Learning Analytics in Competency-Based Medical Education	Thoma B. and colleagues	2021	Canada	Conceptual/ theoretical analysis	Graduate/ Residency
16	Learning Analytics Applied to Clinical Diagnostic Reasoning Using a Natural Language Processing–Based Virtual Patient Simulator: Case Study	Furlan R. and colleagues	2022	Italy	Case study	Graduate/ Residency
17	Empowering Health Care Education Through Learning Analytics: In-depth Scoping Review	Iva Bojic I. and colleagues	2023	Singapore	Scoping review	Mixed
18	Learning Analytics in Virtual Laboratories: A Systematic Literature Review of Empirical Research	Elmoazen R. and colleagues	2023	Finland	Systematic review	Undergraduate
19	Using Learning Analytics in Clinical Competency Committees: Increasing the Impact of Competency-Based Medical Education	Carney PA. and colleagues	2023	USA	Case study	Graduate/ Residency
20	Frameworks for Integrating Learning Analytics with the Electronic Health Record	Pusic MV. and colleagues	2023	USA	Conceptual framework/ Perspective	Mixed

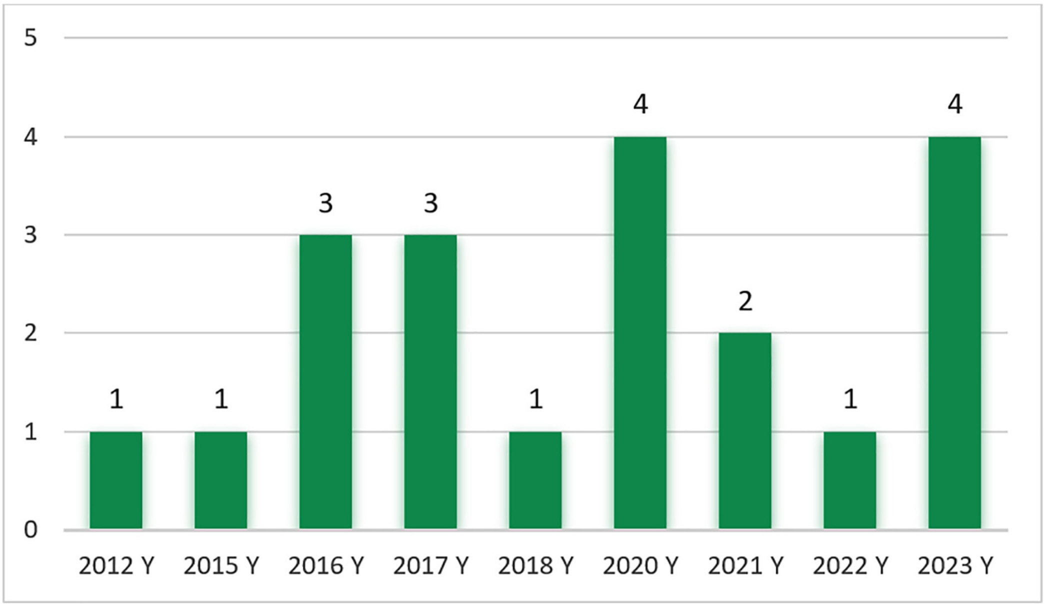

Figure 2: Number of included articles between 2010 and 2023

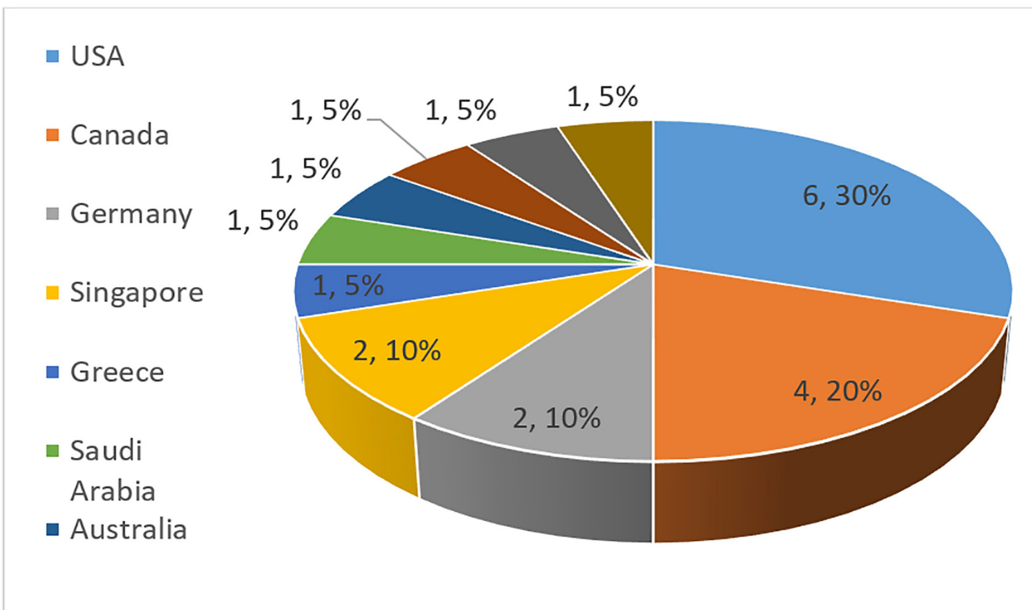

Figure 3: Geographical Distribution of Included Studies by Country

Table 2 shows the application, benefits and challenges of learning analytics in medical education, and Table 3 shows key findings and information obtained from the reviewed articles, which is essentially a mixed extraction of definitions, applications, and outcomes.

Discussion

This scoping review synthesized evidence from 20 studies on learning analytics in medical education, focusing on its definition, applications, benefits, and challenges. The main findings demonstrate that learning analytics has been used to personalize education, predict learner performance, support Competency-Based Medical Education (CBME), and inform curriculum improvement. At the same time, its adoption remains limited by concerns regarding data privacy, technical capacity, and alignment with educational outcomes.

Table 2: Applications, benefits and challenges of learning analytics

Main Category	Related Theme	Description	Supporting Studies
Applications of learning analytics	Personalized learning and feedback	LA tools track learner progress and provide tailored feedback to enhance engagement and self-regulated learning.	(4, 6, 18, 20, 26-29)
	Early identification of at-risk learners	Predictive analytics models identify students who may require additional support to prevent failure or attrition.	(29-32)
	Curriculum evaluation and improvement	Aggregated data used to review curricular design, course delivery, and competency outcomes.	(29, 32-34)
	Support for CBME	LA supports progress tracking, entrustment decisions, and data-driven evaluation of competencies.	(32, 35-37)
	Simulation and clinical reasoning	LA applied in simulation platforms to assess decision-making, diagnostic accuracy, and procedural performance.	(14, 17, 35, 37)
	Learning dashboards and visualization tools	Dashboards visualize learner data to inform students and faculty about progress and outcomes.	(27, 28, 34, 36)
Benefits of learning analytics	Enhanced learner engagement and motivation	Personalized insights and adaptive feedback improve motivation and learner ownership.	(4, 18, 20, 26-28)
	Data-driven decision-making	Educators use data analytics to guide interventions and resource allocation.	(29, 32-34)
	Improved academic performance and competency achievement	Use of LA correlates with better exam performance and timely progression in CBME.	(30-32)
	Faculty support and curriculum management	Aggregated analytics aid in faculty mentoring, course evaluation, and curriculum redesign.	(32, 34, 36)
Challenges and barriers of learning analytics	Discrepancy with final clinical performance	Analytics-based predictions do not always align with real-world clinical competence outcomes.	(30, 34)
	Risk of privacy violations	Use of learner performance data introduces risks of unauthorized access or misuse.	(11, 20, 30, 34, 36)
	Ignoring learners' learning pathways	LA systems may oversimplify learning processes and overlook individual differences.	(34, 42)
	Creating stress in learners	Continuous monitoring may increase anxiety and reduce intrinsic motivation.	(34, 43)
	Burdening instructors with data collection	Faculty workload increases due to added responsibility for gathering and interpreting analytics.	(11, 20, 34, 42)
	Concerns about data ownership, governance, and validity	Ambiguity exists regarding who owns data and whether analytics are valid and reliable.	(11, 20, 30, 34, 36)
	Ethical issues in access and governance	Questions arise about consent, data access rights, and ethical data use in education.	(11, 34, 36)
	Faculty time required for interpretation	Instructors may lack time to analyze dashboards or interpret complex analytics reports.	(11, 20, 34)
	Lack of technical and contextual expertise	Institutions may not have specialists trained in analytics or educational data science.	(1, 20, 30, 34, 36)

Main Category	Related Theme	Description	Supporting Studies
	Imprudent data mining	Poorly designed algorithms can lead to misleading interpretations or biased outcomes.	(11, 30, 34)
	Insufficient data availability	Many medical education contexts lack large, machine-readable datasets needed for analytics.	(1, 17, 29, 31, 44)
	Difficulty identifying strengths and weaknesses	Analytics may not accurately capture nuanced learner competencies.	(11, 31)
	Data quality issues	Incomplete, inconsistent, or low-quality data reduce analytics accuracy.	(1, 17, 31, 44)
	Ethical and privacy issues in sensitive data	Handling data tied to clinical performance raises heightened ethical concerns.	(11, 30, 34, 42)
	Resistance to innovation and change	Faculty or institutions may resist adopting analytics due to fear of surveillance or change.	(32, 34)
	Technical challenges	System integration, interoperability, and platform limitations hinder implementation.	(30, 32, 34, 36)
	Lack of understanding of learning analytics	Educators and learners may lack literacy in interpreting analytics or using insights effectively.	(32, 34, 36)

*LA: Learning Analytics; CBME: Competency-Based Medical Education

Table 3: Information obtained from the reviewed studies

	Title	Authors	Year	Details
1	Learning Analytics: A Case Study of The Process of Design of Visualizations (38)	Olmos M. and colleagues	2012	Definition: The measurement, collection, analysis, and reporting of data about learners and their contexts, for the purpose of understanding and optimizing learning and the environments in which it occurs. Domains: Technical (data mining), educational (learning analytics), administrative challenges. Applications: Support decision-making and enhance learning outcomes. Levels Academic analytics: Aiming to provide analysis at the institutional or national level. Learning analytics: At the course or faculty level.
2	A Conceptual Analytics Model for an Outcome-Driven Quality Management Framework as Part of Professional Healthcare Education (1)	Hervatis V. and colleagues	2015	Domains: Focus on technical challenges (e.g., educational data mining), Educational challenges (e.g., learning analytics), Administrative challenges (e.g., academic and practical analytics). Applications: Using large data from online environments; learner modeling for personalization, identify misconceptions, provide feedback, improve outcomes, and understand processes.
3	Using Learning Analytics to Identify Medical Student Misconceptions in an Online Virtual Patient Environment (4)	Poitras EG. and colleagues	2016	Definition: Collecting and processing big data. Applications: Enhancing education, recognizing effective strategies, monitoring progress, enabling timely interventions, and delivering feedback. Methods: Micro (throughout the learning process) / macro (by collecting educational data for future use)-interventions.

	Title	Authors	Year	Details
4	Process-Oriented e-Learning System for Training Healthcare Professionals on Big Data Usage (35)	Karabetsou V. and colleagues	2016	Definition: Collecting and processing big data with volume, variety, and velocity. Methods: Visualization, network/semantic analysis, data mining (prediction, clustering, rules). Advantages: Improve instructional delivery, outcomes, curriculum design, and teacher performance. Challenges: Data quality, lack of learning science connection, ethics/privacy.
5	Introduction: Analytics Research and Case Studies in Online Learning (30)	Vignare K. and colleagues	2016	Definition: Gathering and analyzing data patterns to evaluate learner readiness and performance. Applications: Evaluating preparedness, detecting problems, creating interventions, targeting at-risk students, customizing learning experiences, forecasting outcomes, adapting instruction, and encouraging deeper understanding.
6	How Learning Analytics Can Early Predict Under-Achieving Students in A Blended Medical Education Course (31)	Saqr M. and colleagues	2017	Purpose: Analyzing learners' online data to improve the learning process and optimize learning environments. Applications: Understanding assessments, addressing system inquiries, evaluating learning processes and results, and assisting learners. Challenges: Limited time, security concerns, lack of specialized skills, inadequate data mining methods, and insufficient data availability.
7	The Flipped Classroom and Learning Analytics in Histology (27)	Gilliland KO.	2017	Definition: Examining process data to improve the learning experience. Applications: Enhance learning, track engagement/progress, document achievements, improve feedback, generate metacognitive insights, faculty development.
8	A Big Data and Learning Analytics Approach to Process-Level Feedback in Cognitive Simulations (39)	Pecaric M, and colleagues	2017	Definition: Measuring, collecting, analyzing, and reporting data about learners and their learning environments. Tasks: Monitor current performance and generate predictions about future outcomes. Applications: Predict slow progress, early warnings, improve outcomes, highlight active learners, predict scores, provide feedback, track participation, share insights, identify at-risk.
9	Learning Analytics in Medical Education Assessment: The Past, The Present, and the Future (11)	Chan T. and colleagues	2018	Applications: Learner and system performance insights, programmatic assessment support, analysis of learning processes and outcomes, learner support and enhancement through analytics. Challenges: Limited faculty time for managing data, data security risks associated with large datasets, and inadequate technical expertise.
10	Click-Level Learning Analytics in An Online Medical Education Learning Platform (40)	Matthew M. and colleagues	2020	Definition: Measuring, collecting, analyzing, and reporting data about learners and their learning environments. Applications: Monitoring learner progress and identifying individuals who require additional support.
11	Team-Based Learning Analytics: An Empirical Case Study (28)	Koh YYJ. and colleagues	2020	Definition: Measuring, collecting, analyzing, and reporting data about learners and their learning environments. Applications: Improving learning conditions, providing personalized feedback, informing topic selection, and guiding instructional planning.

	Title	Authors	Year	Details
12	The Use of Learning Dashboards to Support Complex In-Class Pedagogical Scenarios in Medical Training: How Do They Influence Students' Cognitive Engagement? (41)	De Leng B. and Pawelka F.	2020	Definition: Measuring, collecting, analyzing, and reporting data about learners and their learning environments. Applications: Enhancing instructional practices, directing learners to appropriate resources, assessing learner progress and curriculum effectiveness, and forecasting academic performance. Challenges: Misalignment with clinical, privacy risks, overlook pathways, stress, data governance, faculty burden.
13	Ten Caveats of Learning Analytics in Health Professions Education: A Consumer's Perspective (34)	Ten Cate O. and colleagues	2020	Definition: Measuring, collecting, analyzing, and reporting data about learners and their learning environments. Applications: Identifying priorities, curriculum development.
14	Image Interpretation: Learning Analytics-Informed Education Opportunities (42)	Thau E. and colleagues	2021	Definition: Measuring, collecting, analyzing, and reporting data about learners and their learning environments. Applications: To enhance education, support faculty development and evaluation, improve quality of care, promote equity, and connect assessments with outcomes. Challenges: Security, ownership, ethics.
15	From Utopia Through Dystopia: Charting a Course for Learning Analytics in Competency-Based Medical Education (36)	Thoma B. and colleagues	2021	Definition: Collecting, analyzing, and interpreting data generated by learners. Applications: Understanding learning processes, improving learning outcomes, revealing expertise and reasoning patterns, and delivering targeted feedback.
16	Learning Analytics Applied to Clinical Diagnostic Reasoning Using a Natural Language Processing–Based Virtual Patient Simulator: Case Study (43)	Furlan R. and colleagues	2022	Definition: Collecting, analyzing, and interpreting data generated by learners. Purpose: To understand and influence learning processes. Applications: Improving outcomes and feedback, identifying and supporting at-risk Challenges: Stakeholder resistance, limited awareness or expertise, and technical constraints.
17	Empowering Health Care Education Through Learning Analytics: In-depth Scoping Review (32)	Iva Bojic I. and colleagues	2023	Definition: Measuring, collecting, analyzing, and reporting data about learners and their learning environments. Purpose: Optimizing learning and the contexts. Applications: Enhancing learner outcomes, understanding, interpreting, and shaping learning processes and experiences, Providing feedback to learners. Challenges: Resistance to innovation and change, lack of understanding of learning analytics, technical challenges, providing additional support to learners at risk of failing a course.

	Title	Authors	Year	Details
18	Learning Analytics in Virtual Laboratories: A Systematic Literature Review of Empirical Research (44)	Elmoazen R. and colleagues	2023	Definition: Interpretation of data to assess progress/predict/identify issues. Purpose: Enhancing and optimizing the educational experience for learners and instructors. Applications: Active learning support, decision-making, Predicting learner scores and success, and so on.
19	Using Learning Analytics in Clinical Competency Committees: Increasing the Impact of Competency-Based Medical Education (29)	Carney PA. and colleagues	2023	Definition: Interpretation of data for progress/prediction/issues. Applications: Adaptive learning, individualized feedback, improve outcomes, professional development.
20	Frameworks for Integrating Learning Analytics With the Electronic Health Record (37)	Pusic MV. and colleagues	2023	Definition: Interpretation of a wide range of data generated and collected by learners to assess progress, predict future performance, and identify potential issues. Applications: Adaptive learning, Providing individualized feedback, Improving educational outcomes, Professional development

While learning analytics has been widely explored in general higher education (29, 32), its use in medical education is still emerging. What sets learning analytics apart from other educational approaches is its structured collection and analysis of learner data to guide educational systems. This evidence-based approach enables more precise decisions for students, educators, and institutions, yet its potential is not fully realized in the education of healthcare professionals.

The review demonstrates that learning analytics is most effective in structured, digital learning environments, where learner interactions can be systematically tracked and analyzed (4, 42). Personalized feedback, early identification of at-risk students, and adaptive learning were consistently reported as key benefits across the reviewed studies (4, 6, 18, 20, 27, 28, 32, 42). These outcomes suggest that learning analytics can enhance learner engagement and optimize educational interventions (14, 18, 35, 37). Nevertheless, the limited adoption in clinical environments reflects challenges in capturing complex, real-world performance data (34, 41), highlighting a gap between digital and workplace-based education.

Across the included studies, there was substantial agreement regarding the potential of learning analytics to improve learning outcomes. Eight studies emphasized personalized learning and feedback (4, 6, 18, 20, 27, 28, 32, 42), whereas four studies explored applications in simulation or clinical reasoning (14, 18, 35, 37), indicating uneven integration across educational contexts. Variations in definitions and conceptual frameworks were minor, generally reflecting differences in educational focus rather than fundamental disagreements (1, 29). Methodological heterogeneity—ranging from case studies to predictive models—also underscores the early stage of learning analytics research in medical education (32, 38).

Most studies adopted Siemens' definition of learning analytics as the "*Measurement, collection, analysis, and reporting of data about learners and their contexts, for purposes of understanding and optimizing learning and the environments in which it occurs* (27, 28, 31, 33, 34, 36, 38, 41) ." A minority provided variations emphasizing competency-based education (36), simulation feedback (39), or diagnostic reasoning (43). Thus, while definitions were largely consistent, subtle differences reflected the educational focus of each study. Importantly, there was no contradictory conceptualization, which suggests that the field shares a common foundation but diverges in application contexts.

In medical education, learning analytics lies at the convergence of learner performance data and statistical modeling approaches. At the curriculum level, learning analytics can support program administrators and accreditation or authorization committees by facilitating the interpretation of assessment data to inform decision-making. More broadly, it enables the investigation of system-level issues and the identification of challenges that may influence educational programs. Accordingly, learning analytics applies statistical and computational techniques to analyze diverse data sources in order to describe, explain, and predict learners' behaviors and learning processe (11).

Furthermore, analytics is conducted at two distinct levels: academic analytics and learning analytics. Academic analytics concentrates on analysis at the institutional or national level, whereas learning analytics focuses on the course or faculty level (38). Additionally, Vassilis and colleagues categorized analytics into three main areas: those addressing technical challenges (e.g., instructional data mining), those targeting educational challenges (e.g., learning analytics), and those concerned with administrative challenges (e.g., scientific and practical analysis) (1).

Eric and colleagues investigate the application of learning analytics techniques in a virtual online patient setting, stating that investigating misconceptions that lead to diagnostic errors can be challenging in real clinical settings (4, 45). Beyond offering meaningful opportunities for practicing clinical reasoning and receiving feedback, online learning platforms enable educators and researchers to monitor and document learners' interactions, thereby gaining insights into learning processes (4-6). Learning analytics approaches can leverage the large volumes of data produced in such environments, and the application of these analyses to tailor instruction to individual learners is known as learner modelling (6).

Learning models enable training systems to monitor and analyze learner interactions in order to select and deliver optimal instructional content and tailor feedback to support improved learning outcomes. Moreover, learning analytics methods offer a unique opportunity to leverage data generated by authentic learners in real educational contexts, thereby deepening understanding of how learning occurs. This study demonstrates how automated approaches can be applied to detect learner misconceptions, generate theory-driven hypotheses, and deliver individualized feedback to facilitate more effective learning. In medical education, learning analytics has been applied to identify misconceptions, personalize feedback, tailor instruction and content delivery, enhance learning outcomes, and gain deeper insights into learning processes (4).

Learning analytics has many advantages in medical education. It creates the potential to optimize learning experiences and outcomes by monitoring their experiences or performance throughout their academic career. The reviewed studies indicate that its most frequent applications include delivering timely feedback, supporting personalized and adaptive learning, recommending appropriate educational content, and enhancing learning outcomes. In addition, learning analytics facilitates a deeper understanding of learning processes, enables the tracking of learner progress with timely interventions, helps identify students at risk, and supports curriculum improvement. It also contributes to ensuring adequate coverage of learning outcomes and clinical competencies, optimizing the quality and cost-effectiveness of care, and informing changes at the individual, programmatic, and system levels. Furthermore, learning analytics allows for more personalized educational experiences and the prediction of future professional performance.

Accordingly, learning analytics has been implemented across diverse domains in medical education. Based on the findings of the current review, eight studies demonstrated its capacity to personalize learning and deliver feedback by detecting misconceptions, adapting instruction, and fostering self-regulated learning (4, 14, 18, 20, 29, 31, 42, 43). Six studies employed predictive models to identify learners at risk of underperformance or dropout (17, 20, 31, 36, 42, 43). Five studies utilized dashboards and aggregated learner data to support curriculum enhancements and institutional decision-making (20, 30, 34, 36, 42). In simulation-based training and clinical reasoning, four studies applied analytics to refine diagnostic skills and decision-making processes (14, 18, 39, 43). Additionally, three studies highlighted analytics as a supportive tool for competency committees in CBME (20, 34, 36). These applications reveal that learning analytics performs optimally in structured, digital learning environments where large datasets enable systematic analysis, though its adoption in workplace-based clinical education remains limited.

Given the growing body of research highlighting the importance of learning analytics in medical education, it is important that universities examine the application of learning analytics and understand its benefits and challenges. The most important challenge, which was identified in this study, is the challenge related to ethical issues in the use of data and the ownership and governance of data. In addition, other challenges include ignoring learning paths, stressing learners to increase efficiency, overburdening professors with data collection and taking time and energy from teaching, resistance to innovation and change, lack of understanding of learning analytics, and lack of technical and contextual expertise required for analysis.

Despite its benefits, several challenges were consistently identified. This study identified ethical considerations—particularly issues related to data use, ownership, and governance—as the most significant challenge in applying learning analytics (11, 20, 30, 34, 36, 42, 43). For data quality and sufficiency, five studies noted fragmented or incomplete records (1, 17, 29, 31, 44, 46). Concerning faculty workload and time burden, four studies addressed the increased workload and time demands on faculty, such as additional instructional duties (11, 20, 34, 42).

On technical expertise and infrastructure, five studies reported lack of analytic capacity and integration difficulties (1, 20, 30, 34, 36). Two studies linked learner stress to heightened anxiety from constant monitoring (34, 43). Finally, regarding misalignment with clinical competence, certain studies indicated that analytics results did not reliably forecast clinical skills (30, 34), in contrast to others showing positive correlations (14, 18, 43).

The included studies were heterogeneous in design (such as case studies, predictive models, reviews) and educational levels (including undergraduate, graduate, residency, continuing education). However, few studies compared analytics across levels or assessed transferability between digital and clinical learning environments. Moreover, most studies were exploratory or descriptive; rigorous evaluations of effectiveness were sparse.

To our knowledge, no prior scoping review has synthesized applications, benefits, and challenges of learning analytics specifically in medical education. Previous reviews focused on higher education more broadly (21, 22, 32, 47). This gap underscores the need for systematic evaluation of learning analytics in medical contexts, particularly regarding its validity in predicting clinical competence.

Limitations and Suggestions

Restricting the review to studies published between 2010 and 2024 may have resulted in the omission of earlier theoretical and conceptual work. Moreover, the lack of a formal critical appraisal limits the ability to draw firm conclusions regarding the methodological quality of the included studies. The relatively small number of eligible articles also highlights the emerging nature of learning analytics research within medical education. These findings suggest that policy efforts should prioritize the development of clear governance frameworks addressing data privacy, ethical use, and ownership, while in practice, medical schools should integrate learning analytics within structured digital platforms alongside strategies to manage faculty workload and support professional development. Future research should focus on examining the effects of learning analytics on clinical competence and patient outcomes, establishing standardized reporting frameworks, comparing implementations across educational levels and contexts, and identifying approaches that balance learner autonomy with effective monitoring.

Conclusion

This review provides a comprehensive synthesis of applications, benefits, and challenges, offering a structured overview that can inform future scholarship, while the transparent five-step scoping review framework enhances reproducibility. The findings suggest that learning analytics offers valuable potentials to increase personalized learning, identify at-risk students, support competency-based education, and inform curriculum design. However, its implementation is constrained by ethical concerns, technical barriers, data quality issues, and limited validation against clinical outcomes.

There is a notable lack of robust, outcome-focused research in this area. Future studies should emphasize connecting learning analytics to clinical competence, addressing privacy and governance issues, and developing frameworks that support sustainable integration in medical education.

Abbreviations

CBME: Competency-Based Medical Education

LA: Learning Analytics

PRISMA-ScR: Systematic Reviews and Meta-Analyses Extension for Scoping Reviews

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Authors’ Contribution

ZS designed the study. FK and ZH assisted with the review of the articles. ZH made the primary contribution to drafting the manuscript. EK reviewed the manuscript and provided feedback. All authors reviewed and approved the final manuscript.

Conflict of interest

The authors report that there are no conflicts of interest.

Ethical Considerations

This study received ethical approval from the Ethics Committee of Iran University of Medical Sciences (IUMS), Tehran, Iran, in 2021 (Ethics code: IR.IUMS.REC.1400.1052).

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Availability of Data and Materials

All data utilized in this study are openly available through public databases and repositories.

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