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A State-of-the-Art Review of Applications of Learning Analytics in Education

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Abstract

The advent of Learning Analytics(LA) has ushered in a revolution in the field of education because of the use of data-driven decision-making techniques in education. This study undertakes a state-of-the-art review following the method of Barry et al. (2022) on the applications of LA in education. Using a predefined search strategy, the researchers retrieved 24 articles from the *Scopus* database that are related to the topic and reviewed them in a table format. Critical research gaps like causal research between LA interventions and student performance and ethical frameworks to be developed for fair and transparent, and real-time adaptive systems are highlighted. The study found that development of LA has passed from the stage of simple descriptive analytics to sophisticated predictive and prescriptive models. The key areas of LA application were student performance prediction and at-risk identification, learning process and behaviour understanding, curriculum and course design improvement. Also, the literature under consideration suggested the growing importance of user perceptions of fairness, transparency and effective dashboard design for successful implementation of LA.

Keywords: Learning Analytics, Data Mining, Student Performance Prediction, State-of-the-Art Review

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1.Introduction

Over the past few years, there has been a revolutionary change in the educational environment that has been brought about by the combination of technology and data analytics. Learning Analytics(LA), which is the measurement, collection, analysis, and reporting of data regarding learners and their situations, has become a central instrument in the improvement of educational outcomes (Freitas et al., 2019). The development of the field has led to the evolution of the initial descriptive reporting in the learning management systems towards more advanced predictive and prescriptive models that seek to offer real-time and individualized feedback (Sabri et al., 2025). With the maturation of the field, scholars are becoming more adamant about the necessity to move beyond mere predictive modelling and towards explainable artificial intelligence(XAI) and prescriptive analytics(PA) that can provide actionable interventions to promote student success (Sghir et al., 2022; Susnjak, 2023).

With the growing presence of digital platforms and tools in educational institutions, the amount of data generated has been growing exponentially, and educators and administrators have the opportunity to learn about the performance, engagement, and learning behaviours of students (Murumba, 2022). With LA, it will be possible for the stakeholders to tailor the learning experience, identify at-risk learners, and eventually improve retention and student success (Manzoor, 2016). This review paper is a synthesis of the contemporary literature and case studies that provide an in-depth look at the applications of LA in different settings of education ranging from K-12 to higher education. This new review paper is meant to examine the varied applications of LA in education, with particular focus on some of the key trends, approaches, and the impact of data-driven decision making on learning and teaching activities. The primary research question to guide the state-of-the-art review is as follows: What are the key applications of Learning Analytics in education?

2.Significance of the Study

Although the research in LA has experienced a swift growth in the past ten years and more, the literature is disjointed in relation to various educational settings, practices and strategies.

Teachers, researchers, and policy-makers do not have a unified comprehension of the way LA is being applied today to predict issues in areas ranging from student achievement to curriculum design to ethical matters. This state-of-the-art review fills this gap, as it is a synthesis of the available literature, which will allow presenting a coherent picture of the current practice, outline the new trends, and point out the areas that need additional research.

3.Method of the study

This state-of-the-art review was conducted based on the framework of Barry et al. (2022). This state-of-the-art review was carried out in order to systematically analyse the various uses of Learning Analytics (LA) in the educational context.

4.Search Strategy and Keywords

This study was carried out based on the extracted documents of *Scopus* database. The search was conducted using a targeted string designed to capture articles focused on the application of learning analytics within educational contexts. The following search query was used:

(TITLE (“Learning Analytic”) AND TITLE-ABS-KEY (education)) AND (LIMIT-TO (LANGUAGE , “English”))

4.1-Search Outcome

The above search resulted in 24 documents in the *Scopus* database. These 24 articles constituted the end corpus of this state-of-the-art review. Studies that focus on applications of learning analytics in education were included in this study.

4.2-Results

The following state-of-the-art review table presents a comprehensive summary of each study, organized chronologically to illustrate the evolution of the field over the years -

Table 1:

State-of-the-Art Review of Learning Analytics Applications in Educational Settings

Author(Year)	Applications of Learning Analytics
Lyn et al. (2024)	In this study, Learning Analytics has been employed to examine the learning trajectories of undergraduate engineering students in a private institution of higher learning in Malaysia, through techniques of dimensional reduction (PCA and NMF) and clustering (K-means and DBSCAN), based on student grade data. Network Graph Analysis has also been applied for cluster discovery and bottleneck courses

	identification.
Schmodde et al. (2024)	The present paper employed Learning Analytics to examine the preferences and perceptions of students and faculty members in higher education concerning the features of LA systems through choice-based conjoint analysis and video vignettes experiments. It was found out that users appreciate “fairness” as the most significant feature, and transparent communication on the issues with the LA system makes institutions more attractive.
Oladipupo & Samuel (2024)	In this paper, Learning Analytics was applied to model student staff interaction patterns from two higher education institutions from Africa through the use of association rule mining (Frequent Pattern Growth). The results were confirmed through Structural Equation Modeling, showing that Poor Quality Interactions, Reflective Learning, and Quantitative Reasoning are important predictors of Student-Staff Interaction.
Zhou & Ye (2024)	In this study, the Learning Analytics approach has been applied to explore the cognitive engagement patterns of 44 college students involved in the online collaborative learning activities through entropy analysis, sequential pattern mining, and temporal network analysis of the online discourse. It was found that successful groups tended to frequently move into perspective elaboration and had different longitudinal engagement patterns from unsuccessful groups.
Jongile & Ivala (2023)	The application of Learning Analytics theory has been carried out in this paper in the context of enhancing the identification process of at-risk students in higher education through an inductive analysis of literature and formulation of a modified theoretical model using Tinto's longitudinal model of attrition. The use of the model will incorporate institutional data in order to make real-time interventions.
Llerena-Izquierdo et al. (2023)	Learning Analytics was utilized in this study as the tool to observe and modify assessments of engineering students using a virtual learning environment by creating a model that follows the students’ actions to give suggestions to teachers. As a result, there was an average pass rate

	of 87% in four subjects and was able to prevent external risks such as low connectivity.
Talebinamvar & Zarrabi (2022)	The current study employed Learning Analytics for creating homogeneous groups of college students on the basis of their writing behavior by using dimensionality reduction and clustering on keystroke logs data. In this way, five unique writer profiles (such as Strategic planners, Low-performers etc.) have been found out in order to provide customized feedback on the process of writing.
Wibawa et al. (2021)	In this study, Learning Analytics was used to summarize the use of data mining techniques in predicting and improving the learning success of students in different educational environments through the discussion of common approaches like classification, clustering, and association mining. The purpose of the study was to examine students' backgrounds and interactions and provide teachers with insights for designing new learning performance tools..
Sujatha & Uma Maheswari (2021)	This paper used Learning Analytics to create a preventive feedback mechanism for students and faculty in a post-graduate management program by deploying logistic regression to predict academic status in foundation courses and stepwise regression to predict capstone course marks. The analysis found that prior board exam scores become irrelevant after the first semester, while first-semester performance becomes a dominant predictor.
Thiruppugal (2020)	This paper used Learning Analytics to assess the role of Learning Analytics Dashboard (LAD) design in optimizing learning for higher education students by developing a prototype of a student-facing LAD based on implications from previous studies. The study concluded that effective design principles can positively influence student motivation, engagement, and achievement.
Adji & Hamda (2019)	This paper used Learning Analytics to measure student participation levels in an online Chemistry Education course at the Open University by tracking metrics such as material access counts, discussion forum reads, and response uploads. This data was used to quantify

	engagement and visually map interaction patterns between students and tutors throughout the semester.
Bertacchini et al. (2019)	This paper used Learning Analytics to compare the learning outcomes of university students taught analytic mechanics with and without computer simulations by analyzing four groups of students (experimental vs. control). The analysis found that the experimental groups not only performed better overall but also demonstrated deeper comprehension, better problem-solving, and greater development of personal ideas.
Šovčíková (2019)	This paper used Learning Analytics to verify the effectiveness of using ICT to teach analytic geometry to grammar school pupils by comparing a control group (traditional instruction) with an experimental group (technology-integrated instruction). The results confirmed the hypothesis that pupils achieve significantly better results when technology is incorporated into the teaching and learning process.
Nurhasanah et al. (2018)	This paper used Learning Analytics to examine the abstraction process of pre-service mathematics teachers in learning Analytic Geometry by using descriptive statistics to analyze test scores from three different assessments. The analysis revealed a linear association between higher levels of abstraction in learning Parallel Coordinates and higher student achievement in the standard Analytic Geometry course.
Huang et al. (2017)	This paper used Learning Analytics to improve video-based learning for learners in MOOC-style ShareCourse programs in Taiwan by proposing the “VideoMark” approach, which analyzes learner interactions with video content. The findings are presented as a visual keyword cloud, helping learners review, consolidate, and clarify specific concepts.
Aguilar Castro & Valdiviezo-Diaz (2017)	This paper used Learning Analytics to understand and evaluate the learning process within a smart classroom environment by defining a set of analytic tasks using data mining techniques. These tasks analyzed student scores, skills development, and behavior in

	assessment questions to provide feedback on the evaluation process and pedagogical practices.
Hu et al. (2017)	This paper used Learning Analytics to visualize collaborative work on Wikis built by secondary school students by enhancing the Wikiglass tool with new features including flexible date range selection and revision network visualization. These features, along with thinking order detection, are currently being evaluated in two Hong Kong secondary schools.
González-Eras et al. (2017)	This paper used Learning Analytics to guide the adaptation process of a smart classroom learning environment by proposing an extension of autonomic cycles that utilizes student competency data as a service. This allows the environment to adapt in real-time to strengthen specific competencies during the learning process.
Toetenel & Rienties (2016)	This paper used Learning Analytics to analyze the learning design decisions of educators across courses taken by over 60,000 students by examining 157 learning designs. The analysis found that educators predominantly use assimilative and assessment activities, and that a high proportion of assimilative activities is negatively correlated with student outcomes.
Hu et al. (2016)	This paper used Learning Analytics to visualize statistics and timelines of collaborative Wiki projects built by secondary school students by developing the Wikiglass tool with a modular Model-View-Controller framework. It displays collaborative data, enabling teachers in Hong Kong to monitor and evaluate group projects in inquiry-based learning.
Aguilar Castro et al. (2016)	This paper used Learning Analytics to provide knowledge about learning activities within a Smart Classroom to improve student performance by proposing a framework where LA is organized as a closed cycle of tasks. These tasks generate metrics that are used as feedback to optimize the pedagogical model proposed by the smart classroom.
Firat (2016)	This paper used Learning Analytics to investigate the effects of

	undergraduate students' LMS learning behaviors on their academic achievements by tracking online behaviors for 14 weeks. The analysis found that students used the LMS most intensively on course days, and that the LMS only helped increase achievement when it included features like interaction, reinforcement, and attractive design.
BenSassi et al. (2015)	This paper used Learning Analytics principles to pre-evaluate learning scenarios and predict learner behavior by proposing a framework using formal methods to analyze contextual elements (time, actors, network) and correlations between activities. The goal is to reveal inconsistencies and ambiguities in learning scenario design before implementation.
Zupanc et al. (2009)	This paper used Learning Analytics to provide feedback on teaching effectiveness for upper secondary education in Slovenia by describing an online data selection and analysis tool that uses national Matura exam data. This tool helps subject testing committees, schools, and teachers analyze effectiveness and plan future instructional activities as part of a continuous quality assurance process.

5.Discussion

This state-of-the-art literature review combined the uses and results of LA in 24 studies published between 2009 and 2024 and identified a diverse environment of data-driven insights reshaping higher education and secondary learning settings. The analysis proves that LA has developed beyond simple descriptive analytics, including the monitoring of student engagement with Learning Management Systems (Adji and Hamda, 2019; Firat, 2016), to more advanced predictive and prescriptive models that utilize machine learning, clustering algorithms, and network analysis (Lyn et al., 2024; Talebinamvar and Zarrabi, 2022).

One of the most important discoveries is the variety of LA applications. Some of the studies on the prediction of student performance and identification of the at-risk groups, based on regression models (Sujatha & Uma Maheswari, 2021) and theoretically-based frameworks (Jongile & Ivala, 2023) to make early interventions. Other focused on the learning process and behaviour, using the sequential pattern mining to decode cognitive engagement in collaboration (Zhou & Ye, 2024) or keystroke analysis to profile student writers (Talebinamvar & Zarrabi,

2022). Designing curriculum and courses was also a leading role of LA, with network analysis indicating bottleneck courses (Lyn et al., 2024) and learning design analytics showing a negative relationship between assimilative activities and student outcomes (Toetenel & Rienties, 2016).

Moreover, the review also points out the increased significance of human-related aspects in LA implementation. Research by Schmodde et al. (2024) and Thiruppugal (2020) emphasizes the importance of the LA tools not only in terms of technical accuracy but also of user perceptions of fairness, transparency, and efficient dashboard design. Altogether, these articles prove that LA can be a highly effective tool in promoting data-driven decision-making, improving pedagogical processes, and eventually increasing student engagement and performance in various educational settings, including grammar school mathematics (Sovcikova, 2019) or postgraduate management courses (Sujatha & Uma Maheswari, 2021).

6.Conclusion and recommendations for future research

This review illustrates Learning Analytics (LA) in a more dynamic framework. The review discusses the utility of LA in a variety of learning situations, including the prediction of learner performance, identification of at-risk learners, analysis of learning activities, provision of support for learning, and improvement of curricula. In addition to the advancements in technology and analytics of LA, the review describes the relevance of human factors, including fairness, transparency, privacy, explainability, and the user-centred design of dashboards and other visualizations, to the success of LA systems. Overall, the advances discussed in the review demonstrate the capacity of LA to provide a basis for more effective decision making, and to improve the practice of pedagogy and learning, in a variety of different contexts.

Based on the synthesis of this review, the following guidelines for future research in Learning Analytics are recommended:

i. **Establish Causal Evidence for Learning Analytics Effectiveness**: Most reviewed studies have focused on predicting student performance and identifying learning patterns using observational and predictive approaches. Future research should employ longitudinal and experimental designs to establish whether Learning Analytics interventions directly improve student learning outcomes, engagement, and academic achievement.

ii. **Make Learning Analytics Fair and Trustworthy:** Recent studies have emphasized the importance of fairness, transparency, and privacy in Learning Analytics systems.

Future research should focus on developing explainable, ethical, and privacy-preserving frameworks that enhance stakeholder trust while ensuring the responsible use of learner data.

iii. **Build Systems That Respond to Students in Real Time:** Future researches should be done on creating a tool that can modify lessons in real-time or give personalized feedback using live data and make learning analytics an interactive component of the classroom instead of a post-factum report card.

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