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Intelligent systems and their application in the evaluation of university academic performance: A literature review in the South American context

Sistemas inteligentes y su aplicación en la evaluación del desempeño académico universitario: una revisión de la literatura en el contexto sudamericano

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ABSTRACT

The study aimed to analyze the impact of intelligent systems on improving academic performance and personalized learning, through a review of 29 articles published between 2016 and 2024. It focused on the use of artificial intelligence, machine learning, data mining, and intelligent tutoring systems in education. The results showed that these technologies optimize educational assessment and improve academic performance. Predictive models help identify students at risk of dropping out, enabling early interventions. Adaptive architectures proved effective across various disciplines, and intelligent tutoring systems enhanced interaction and feedback. Despite these advances, challenges remain in accessibility in resource-limited environments and ethical concerns related to data privacy and algorithmic bias. The study highlights the need for an inclusive and ethical approach to ensure these technologies transform education and benefit all students.

Keywords: artificial intelligence; educational equity; feedback; machine learning

RESUMEN

El estudio tuvo como objetivo analizar el impacto de los sistemas inteligentes en la mejora del rendimiento académico y la personalización del aprendizaje, mediante una revisión de 29 artículos publicados entre 2016 y 2024. Se centró en el uso de la inteligencia artificial, el aprendizaje automático, la minería de datos y los sistemas de tutoría inteligentes en la educación. Los resultados mostraron que estas tecnologías optimizan la evaluación educativa y mejoran el rendimiento académico. Los modelos predictivos identifican a estudiantes en riesgo de abandono escolar, facilitando intervenciones tempranas. Las arquitecturas adaptativas demostraron ser efectivas en diversas disciplinas, y los sistemas de tutoría inteligentes mejoraron la interacción y la retroalimentación. A pesar de estos avances, persisten desafíos en la accesibilidad en entornos con recursos limitados, y preocupaciones éticas relacionadas con la privacidad de los datos y el sesgo algorítmico. El estudio resalta la necesidad de un enfoque inclusivo y ético para garantizar que estas tecnologías transformen la educación y beneficien a todos los estudiantes.

Palabras clave: aprendizaje automático; equidad educativa; inteligencia artificial; retroalimentación

1. INTRODUCTION

In recent decades, intelligent systems have profoundly transformed the field of educational evaluation, enabling institutions to adopt innovative approaches to measure the performance of students and teachers (Souza & Debs, 2024). Technologies such as artificial intelligence (AI), machine learning, and expert systems have optimized the collection and analysis of educational data, offering more accurate and personalized feedback (Delerna Rios & Levano Rodriguez, 2021; Wang et al., 2024). These advanced tools are helping institutions improve educational quality and adapt to the growing demands of the digital age (Zhai et al., 2021).

The evolution of intelligent systems in education has sparked increasing interest in research on their impact on improving academic performance (García-Martínez et al., 2023). Researchers and educational leaders have begun exploring how these technologies can complement or replace traditional evaluations, which often focus on superficial metrics like grades or attendance (Ali et al., 2024). Instead, intelligent systems can analyze large datasets, allowing for a deeper understanding of learning processes and early detection of student performance issues (Kamalov et al., 2023).

Despite the growing adoption of these systems, their implementation poses several challenges, especially in diverse educational settings. Institutions with varying levels of access to technology and resources face difficulties in effectively integrating these systems (Mhlongo et al., 2023). Additionally, differences in educational contexts, such as institutional size, government policies, and technological infrastructures, affect the standardization of intelligent evaluation practices (Abulibdeh et al., 2024).

Another major challenge is the ethical debate surrounding the use of artificial intelligence in education. Concerns about student data privacy and potential bias in the algorithms used for evaluation have raised criticisms about large-scale implementation (Lim et al., 2023). Although these systems promise greater equity by reducing human bias in assessments, the opacity of certain algorithms and the risk of perpetuating pre-existing inequalities in the education system remain controversial aspects that need to be addressed (Kamalov et al., 2023).

Studies on the application of intelligent systems in educational evaluation highlight both their benefits and limitations. On the one hand, these technologies can facilitate more personalized and adaptive learning environments, significantly improving student performance and engagement (Ali et al., 2024; Gligorea et al., 2023). On the other hand, the lack of clear regulations and international standards hinders the consistent implementation of these tools across different educational contexts, creating disparities in the results obtained (Balasubramaniam et al., 2023).

In this context, the need for deeper research is evident. Current studies focus on exploring how these systems can contribute to the development of more inclusive and equitable educational evaluations. Advances in artificial intelligence and data analytics open new opportunities to identify learning patterns and generate more precise educational interventions, but a critical approach is needed to ensure these innovations are used ethically and effectively (Akinwalere & Ivanov, 2022; Malik et al., 2023).

The objective of this review is to provide a comprehensive overview of research conducted on the use of intelligent systems in evaluating educational performance in the South American context. Through an analysis of scientific literature indexed in databases such as Scopus, this study aims to identify key research trends, knowledge gaps, and the opportunities these systems offer to improve educational quality in various contexts. This research seeks to lay the groundwork for future studies and support the creation of educational policies that promote broader and more effective use of intelligent technologies in evaluation.

2. MATERIALS AND METHODS

2.1. Research characterization

This study was conducted through a literature review to examine and analyze scientific research on the application of intelligent systems in the evaluation of educational performance. A descriptive and quantitative approach was used to analyze the scientific output, including academic articles and other relevant indicators. The purpose was to identify and characterize the available research using data obtained from specialized sources, providing a comprehensive overview of technological trends and challenges encountered in this field.

2.2. Search procedures

In this study, the protocol proposed by Cronin et al. (2008) was followed, which includes the following steps: (1) formulating the research question; (2) establishing inclusion and exclusion criteria; (3) locating relevant articles; (4) evaluating the quality and relevance of the selected literature; and (5) analyzing and synthesizing the findings. To define the selection criteria, the search was limited to materials published between January 2013 and July 2024, focusing exclusively on articles in English and Spanish to ensure an international perspective. The search process was carried out in a single stage, ensuring the thoroughness of the review by strictly applying the defined criteria.

2.3. Search phase in Scopus

In the search phase, the following search term was used: ("intelligent systems" OR "smart systems" OR "automated systems" OR "autonomous systems") AND evaluation AND ("educational performance" OR "academic achievement" OR "learning outcomes" OR "student success") to identify articles related to the use of intelligent systems in the evaluation of educational performance. The keywords included terms covering both the technological aspects of the systems and their application in measuring academic performance and learning outcomes. This search resulted in the identification of 5349 documents, providing a solid foundation for further analysis of trends and challenges in the field.

Subsequently, in addition to the keywords, additional filters were applied to refine the results. Only research articles (LIMIT-TO(DOCTYPE, "ar")) and articles from scientific journals (LIMIT-TO(SRCTYPE, "j")), published between 2016 and 2024 (PUBYEAR > 2015 AND PUBYEAR < 2025), were included. The search was limited to works affiliated with institutions in Latin American countries, specifically Brazil, Colombia, Ecuador, Chile, Peru, Argentina, and Uruguay (LIMIT-TO(AFFILCOUNTRY, "Brazil") OR LIMIT-TO(AFFILCOUNTRY, "Colombia") OR LIMIT-TO(AFFILCOUNTRY, "Ecuador") OR LIMIT-TO(AFFILCOUNTRY, "Chile") OR LIMIT-TO(AFFILCOUNTRY, "Peru") OR LIMIT-TO(AFFILCOUNTRY, "Argentina") OR LIMIT-TO(AFFILCOUNTRY, "Uruguay")). Additionally, the results were filtered to include only articles within the area of Computer Science (LIMIT-TO(SUBJAREA, "COMP")) and written in English or Spanish (LIMIT-TO(LANGUAGE, "English") OR LIMIT-TO(LANGUAGE, "Spanish")). After applying these criteria, a total of 88 documents were obtained for analysis.

Despite applying specific search terms to restrict the results to the use of intelligent systems in the evaluation of educational performance, the initial searches returned a significant number of unrelated works. After reviewing the titles and abstracts, 29 articles were selected for the final review analysis. These articles were considered the most relevant for analysis and provided a solid foundation for evaluating trends and challenges in the use of intelligent technologies in education.

3. RESULTS AND DISCUSSION

Table 1 presents the articles selected for the analysis, detailing the code assigned to each article for easy reference, along with the authors, year of publication, and title of each study and source journal.

Table 1.
Selected articles from Scopus databases

Code	Autors	Title	Journal
A1	(Mellado et al., 2024)	Leveraging Gamification in ICT Education: Examining Gender Differences and Learning Outcomes in Programming Courses	Applied Sciences (Switzerland)
A2	(Díaz & Nussbaum, 2024)	Artificial intelligence for teaching and learning in schools: The need for pedagogical intelligence	Computers and Education
A3	(Zapata-Medina et al., 2024)	Improving the Automatic Detection of Dropout Risk in Middle and High School Students: A Comparative Study of Feature Selection Techniques	Mathematics
A4	(Guanin-Fajardo et al., 2024)	Predicting Academic Success of College Students Using Machine Learning Techniques	Data
A5	(Vives et al., 2024)	Prediction of Students' Academic Performance in the Programming Fundamentals Course Using Long Short-Term Memory Neural Networks	IEEE Access
A6	(Martinez-Carrascal et al., 2024)	Evaluation of Recommended Learning Paths Using Process Mining and Log Skeletons: Conceptualization and Insight into an Online Mathematics Course	IEEE Transactions on Learning Technologies
A7	(Theophilou et al., 2024)	The effect of a group awareness tool in synchronous online discussions: studying participation, quality and balance	Behaviour and Information Technology
A8	(Salazar et al., 2023)	Sentiment analysis in learning resources	Journal of Computers in Education
A9	(Huaman Llanos et al., 2023)	Leveraging Text Mining for Analyzing Students' Preferences in Computer Science and Language Courses	Ingenierie des Systemes d'Information
A10	(Álvarez et al., 2023)	Proposed Model for the Alignment between Curriculum Design and IT	RISTI - Revista Iberica de Sistemas e Tecnologias de Informacao
A11	(Garcia & Lemos, 2023)	The Gamification of E-learning Environments for Learning Programming	International Journal on Informatics Visualization
A12	(Jaramillo-Morillo et al., 2022)	Evaluating a learning analytics dashboard to detect dishonest behaviours: A case study in small private online courses with academic recognition	Journal of Computer Assisted Learning
A13	(de Brito Lima et al., 2022)	Learner behaviors associated with uses of resources and learning pathways in blended learning scenarios	Computers and Education
A14	(Flores et al., 2022)	A New Methodological Framework for Project Design to Analyse and Prevent Students from Dropping Out of Higher Education	Electronics (Switzerland)
A15	(Mendoza et al., 2022)	Assessment of Curriculum Design by Learning Outcomes (LO)	Education Sciences
A16	(Rodríguez et al., 2022)	Using scaffolded feedforward and peer feedback to improve problem-based learning in large classes	Computers and Education
A17	(Pincay-Ponce et al., 2022)	Educational data mining: Incidence of socioeconomic factors on school achievement	RISTI - Revista Iberica de Sistemas e Tecnologias de Informacao
A18	(Melillán & Cravero, 2022)	Software engineering in the development of technologies to support curriculum design: A systematic mapping	RISTI - Revista Iberica de Sistemas e Tecnologias de Informacao

A19	(Vázquez-Cano et al., 2021)	Chatbot to improve learning punctuation in Spanish and to enhance open and flexible learning environments	International Journal of Educational Technology in Higher Education
A20	(Gomez et al., 2021)	Multi-agent systems for the management of resources and activities in a smart classroom	IEEE Latin America Transactions
A21	(Villegas-Ch et al., 2021)	Analysis of the state of learning in university students with the use of a hadoop framework	Future Internet
A22	(Freitas et al., 2020)	IoT system for school dropout prediction using machine learning techniques based on socioeconomic data	Electronics (Switzerland)
A23	(Villegas-Ch et al., 2020)	A business intelligence framework for analyzing educational data	Sustainability (Switzerland)
A24	(Gomede et al., 2020)	Use of deep multi-target prediction to identify learning styles	Applied Sciences (Switzerland)
A25	(Nieto et al., 2019)	Supporting academic decision making at higher educational institutions using machine learning-based algorithms	Soft Computing
A26	(Luna-Urquizo, 2019)	Learning management system personalization based on multi-attribute decision making techniques and intuitionistic fuzzy numbers	International Journal of Advanced Computer Science and Applications
A27	(Alfaro et al., 2019)	Using Project-based learning in a Hybrid e-Learning system model	International Journal of Advanced Computer Science and Applications
A28	(Durães et al., 2019)	Intelligent tutoring system to improve learning outcomes	AI Communications
A29	(Carlotto & Jaques, 2016)	The effects of animated pedagogical agents in an English-as-a-foreign-language learning environment	International Journal of Human Computer Studies

Analysis of technological integration in education

In Table 2, the analysis of technological integration in education reveals how intelligent, automated, and autonomous systems are transforming academic evaluation and personalized learning. Six studies (A2, A4, A5, A9, A22, A25) highlight the use of artificial intelligence (AI) and machine learning to improve academic performance and personalize teaching, while eight articles (A3, A6, A10, A14, A16, A22, A23, A26) focus on automating evaluations, allowing for faster and more accurate analysis of student performance and dropout prediction. Additionally, five studies (A1, A19, A20, A24, A28) explore the use of autonomous systems, such as automated tutors, to facilitate adaptive teaching. The personalization of learning through AI is addressed in seven studies (A2, A5, A9, A11, A13, A17, A26), which demonstrate how these systems adjust educational experiences to individual needs, improving engagement and academic outcomes. Lastly, seven studies (A3, A4, A5, A7, A14, A22, A25) show significant improvements in academic performance, reduction in dropout rates, and optimization of learning pathways due to the integration of these systems.

Table 2.
Topics addressed in the research analyzed

Analysis elements	Frequency (Percentage)	Articles
Intelligent systems in education	6 (20.7%)	A2, A4, A5, A9, A22, A25
Automated systems in assessment	8 (27.6%)	A3, A6, A10, A14, A16, A22, A23, A26
Autonomous systems applied to learning	5 (17.2%)	A1, A19, A20, A24, A28
Personalization of learning through AI	7 (24.1%)	A2, A5, A9, A11, A13, A17, A26

Improvements in academic performance	7 (24.1%)	A3, A4, A5, A7, A14, A22, A25
Intelligent systems in education	6 (20.7%)	A2, A4, A5, A9, A22, A25

Analysis of methodological aspects

Table 3 presents the analysis of the methodological aspects of the selected studies, showing a diversity of approaches used to evaluate the impact of intelligent systems in education. Most studies (A3, A4, A5, A14, A22, A25) employ quantitative methods, using data analysis techniques based on machine learning and artificial intelligence to predict academic performance and student dropout. Other studies (A2, A7, A19, A20) apply mixed approaches that combine quantitative analysis with qualitative evaluations, allowing for a more comprehensive analysis of student experiences and the impact of intelligent systems on personalized learning. Finally, some articles (A6, A9, A17) use experimental methodologies, where systems are implemented in controlled environments to measure their effectiveness in improving academic performance and learning pathways. In summary, the studies show a trend toward integrating large-scale educational data analysis through advanced AI techniques, focusing on personalization and academic performance optimization.

Table 3.
Classification of documents according to methodological aspects

Analysis elements	Frequency (Percentage)	Articles
Quantitative methods	7 (24.1%)	A3, A4, A5, A14, A22, A25, A26
Mixed approaches	4 (13.8%)	A2, A7, A19, A20
Experimental methodologies	3 (10.3%)	A6, A9, A17
Big data analysis	5 (17.2%)	A4, A5, A6, A9, A22
Personalization of learning	6 (20.7%)	A2, A5, A6, A9, A11, A17

Analysis of theoretical elements

Table 4 presents the classification of the articles according to the theoretical frameworks used in the study of methodologies, models, and architectures in the use of intelligent systems applied to education. A large percentage of the articles focus on the use of machine learning models (24.1%) to predict academic performance and student dropout. Other relevant topics include the development of intelligent tutoring and multi-agent systems (17.2%) and the use of adaptive architectures and personalized learning (20.7%). Studies on the analysis of learning pathways and process mining (13.8%) and the use of chatbots and pedagogical agents (10.3%) to improve educational interaction are also highlighted. Additionally, the use of data mining and analysis of large volumes of information (13.8%) is included to optimize academic decision-making and student performance. This classification reflects the diversity of methodological and architectural approaches in the analyzed studies, with a strong focus on using advanced technologies to enhance education.

Table 4.
Classification of articles according to theoretical elements

Analysis elements	Frequency (Percentage)	Articles
Machine learning models	7 (24.1%)	A3, A4, A5, A22, A24, A25, A14
Multi-agent and intelligent tutoring systems	5 (17.2%)	A19, A20, A28, A29, A7
Adaptive architectures and learning personalization	6 (20.7%)	A2, A5, A9, A11, A17, A26
Learning trajectory analysis and process mining	4 (13.8%)	A6, A13, A14, A22
Chatbots and pedagogical agents	3 (10.3%)	A19, A28, A29

Analysis of results

The inferential analysis of the 29 reviewed studies suggests that the implementation of intelligent systems in education is consistently yielding results in terms of improving academic performance, personalizing learning, and optimizing educational management. At a technical level, machine learning models have been the most implemented for predicting academic outcomes, with a predominant focus on identifying students at risk of dropout (A3, A4, A14). However, a key inference is that the success of these tools heavily depends on the quality and quantity of educational data available. Current predictive systems, although accurate in specific contexts, may present biases if not adequately integrated with qualitative variables such as emotions and students' psychological well-being.

Regarding intelligent tutoring and multi-agent systems (A19, A20, A28), the results highlight significant advances in learning personalization and these systems' ability to provide real-time feedback. However, more research is needed on the effectiveness of these systems across different disciplines and educational levels. Currently, most applications have focused on specific areas such as programming (A1, A5, A11), raising the need to expand these systems to other fields of knowledge. The efficiency of intelligent tutors can also be enhanced by integrating emerging technologies such as augmented reality or artificial emotional intelligence, potentially improving student-system interaction.

A promising area of research is the combination of tutoring systems with learning pathway analysis (A6, A13). Studies using process mining and large-scale educational data analysis have demonstrated how these systems can optimize individualized learning paths. However, there is a lack of research on the long-term impact of these technologies. Future research should focus on long-term studies to observe whether these personalized pathways have a lasting effect on academic performance and knowledge retention.

Learning personalization through adaptive architectures and recommendation systems (A2, A5, A9) has proven effective but presents a significant challenge related to scalability and student diversity. Future research should address how these architectures can be adjusted to meet the needs of students with different abilities, learning styles, and socioeconomic backgrounds. Moreover, implementing these technologies in resource-limited institutions remains a challenge. Developing more accessible and cost-effective solutions will be crucial to democratizing the use of these tools globally.

Regarding the interaction between students and intelligent systems through chatbots and pedagogical agents (A19, A29), the results show an improvement in engagement and participation, but current studies have been limited to basic feedback in areas such as punctuation or grammar. Future research should explore how pedagogical agents can evolve to address complex questions and provide more robust support in fields like mathematics and science. Additionally, the use of more advanced natural language processing (NLP) technologies could enable these systems to handle deeper and more personalized interactions.

An important finding is the underutilization of data mining techniques and large-scale data analysis (A17, A21, A23). Although these studies have shown that data mining can improve academic decision-making, more research is needed on how to integrate these approaches with more advanced predictive models. For example, combining data mining with neural network analysis or deep learning could offer a more complex view of student behavior and performance, allowing for more precise and adaptive decision-making.

At the educational management level, the implementation of business intelligence frameworks (A23, A25) has optimized curricular organization and academic planning. However, as these technologies continue to develop, it will be necessary to integrate these systems with more complex educational platforms that consider not only academic data but also metrics of student well-being, engagement, and satisfaction. Future research should focus on developing algorithms that can synthesize this information to provide a more holistic analysis of the educational environment.

Finally, a crucial area for future research is the ethics and social impact of intelligent systems in education. Despite technological advances, challenges related to data privacy and potential bias in the algorithms used

for evaluation and prediction remain. Future studies should address how to mitigate these risks, ensuring that technologies do not perpetuate existing inequalities and are inclusive for all students, regardless of their background.

CONCLUSIONS

The study has shown that intelligent systems, such as machine learning and artificial intelligence, significantly improve academic performance by personalizing learning and accurately predicting success or dropout. Furthermore, the implementation of these systems optimizes educational assessment and facilitates early interventions in at-risk students. However, challenges related to scalability and accessibility have been identified, especially in resource-limited environments. To maximize their impact, it is necessary to develop more inclusive technological solutions that are adaptable to diverse educational contexts, expanding their applicability beyond technical disciplines.

On the other hand, tools such as data mining and intelligent tutoring systems have shown great potential in improving academic decision-making and student-system interaction. Still, their integration into more complex knowledge areas and their ability to offer deep feedback remain areas of future research. In addition, it is essential to consider the ethical implications of these technologies, including data privacy and potential biases in algorithms.

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CONFLICT OF INTEREST

There is no conflict of interest related to the subject matter of the work.

AUTHORSHIP CONTRIBUTION

Conceptualization, data curation, formal analysis, research, visualization, writing - original draft, writing - proofreading and editing: Del-Águila-Castro

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