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Artificial intelligence applications in Latin American higher education: a systematic review

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Abstract

Over the last decade, there has been great research interest in the application of artificial intelligence (AI) in various fields, such as medicine, finance, and law. Recently, there has been a research focus on the application of AI in education, where it has great potential. Therefore, a systematic review of the literature on AI in education is therefore necessary. This article considers its usage and applications in Latin American higher education institutions. After identifying the studies dedicated to educational innovations brought about by the application of AI techniques, this review examines AI applications in three educational processes: learning, teaching, and administration. Each study is analyzed for the AI techniques used, such as machine learning, deep learning, and natural language processing, the AI tools and algorithms that are applied, and the main education topic. The results reveal that the main AI applications in education are: predictive modelling, intelligent analytics, assistive technology, automatic content analysis, and image analytics. It is further demonstrated that AI applications help to address important education issues (e.g., detecting students at risk of dropping out) and thereby contribute to ensuring quality education. Finally, the article presents the lessons learned from the review concerning the application of AI technologies in higher education in the Latin American context.

Keywords: Artificial intelligence (AI), Higher education, Latin America, Machine learning, Deep learning, Natural language processing, Algorithm, Systematic review

Introduction

Artificial intelligence (AI) has become increasingly important in recent decades. It is having a significant impact in numerous fields, such as medicine, finance, law, industry, and entertainment (Amisha et al., 2019; Gade et al., 2020). Education is no exception, and there is a considerable amount of research now underway into AI applications for education, such as intelligent tutoring systems, adaptive learning/teaching, assessment design, and learning analytics (Salas-Pilco & Yang, 2020). AI-based applications for higher education have been growing rapidly across the world and have affected higher education institutions in Latin America, where AI research is being carried out and some AI applications are being implemented to improve university services, help teachers to offer quality education, and support student learning.

Latin America's socioeconomic context creates some challenges for higher education. For example, students who belong to low-income households are more likely to discontinue their studies. However, higher education institutions in Latin America have already started an important restructuring process that involves (a) increasing access to higher education, (b) promoting co-ordination with other universities, and (c) establishing efficacy criteria (Torre & Zapata, 2012). Latin American researchers are currently implementing AI algorithms and using a variety of large educational datasets. AI techniques benefit not only students and teachers but also administrators and decision-makers, who are able to perform their functions more effectively and efficiently through the use of AI, thus improving education quality. With AI applications transforming the landscape of higher education, the extent of AI research in Latin America has increased in recent years. However, there is no comprehensive organization of the findings of various studies for the benefit of researchers, educational authorities, and policymakers. This suggests the urgency of a synthesis and review of AI-related research findings to highlight the innovations that have been brought to higher education by AI to support quality teaching and learning. Therefore, this study set out to provide a conceptual review that systematically maps out the relevant research literature. The article is organized as follows: first, we present the background to AI research, including the Latin American context and the situation of higher education in Latin America. We then describe the methodology, followed by the research results and discussion. Finally, we present a conclusion and some lessons learned from the review.

The following three research questions (RQs) guide the review:

1. RQ1: What and how AI-based applications are being used by higher education institutions in Latin America?
2. RQ2: What are the common AI techniques, software tools, and AI algorithms used in Latin American higher education?
3. RQ3: What education topics and issues are being addressed by AI applications in Latin American higher education institutions?

Background

Artificial intelligence

In 1955, the term *artificial intelligence* was coined by the computer scientists McCarty, Minsky, Rochester, and Shannon (1955/2006). AI is defined as "computing systems that are able to engage in human-like processes such as learning, adapting, synthesizing, self-correction and use of data for complex processing tasks" (Popenici & Kerr, 2017, para. 3). Since then, AI research has grown in cycles, with some dormant periods caused by reduced funding and a lack of effective implementation of algorithms; these periods are known as "AI winters." However, in the last decade, there has been increasing interest in applications of AI to various fields, such as healthcare, industry, and marketing, because of AI's capability to learn and give advice based on digital data. Most AI applications involve the techniques of machine learning, deep learning, and natural language processing, among others.

- *Machine learning* is a subdiscipline of AI that consists of learning algorithms that use available data sources to summarize certain phenomena and further identify patterns. Machine learning systems can be trained or learn to build a predictive model through supervised classification or unsupervised clustering. In education, machine learning can be used to predict students' learning performance and produce personalized learning pathways (Ciolacu et al., 2018).
- *Deep learning* is a type of machine learning technology that uses artificial neural networks through layers of interconnected nodes to simulate the operation of the human brain. Trained deep learning algorithms can make predictions based on very large datasets; this is used, for example, for image recognition (Cheng et al., 2018).
- *Natural language processing* is a field of AI related to understanding the human language through the analysis of sentences and the use of algorithms to extract the meaning of words. One well-known application is chatbots that can understand common language requests and respond automatically, thus providing immediate assistance to users. Another example is automatic language translation (Lu et al., 2020).

Artificial intelligence in education

AI in education started with the introduction of computers to the education sector during the 1990s, and research has focused on developing AI-enhanced learning environments, such as intelligent tutoring systems, adaptive learning systems, intelligent agents, and intelligent collaborative learning systems, that manifest significant improvements in automated computational approaches to education. The education sector is now significantly influenced by AI research, as AI applications are being used by learners, educators, and administrators and various tools, algorithms, and applications have been developed with the capacity to transform the education field (Chen et al., 2020).

According to Zhang and Aslan (2021), AI in education is an interdisciplinary research area integrating computer science, learning sciences, psychology, neuroscience, linguistics, and other disciplines. This interdisciplinary approach is necessary to develop personal, adaptive, and effective learning environments to optimize traditional education. AI has the potential to achieve sustainable change at all levels of the education system, not only in learning and teaching but also in the administration and management of educational institutions. Baker and Smith (2019) listed three main educational processes affected by AI applications in education: (a) learning, with AI being applied to support students' learning processes, such as through the development of adaptive or personalized learning systems; (b) teaching, with teacher workloads being reduced by the automation of feedback, assessment, and administrative tasks; and (c) administration, with AI used for providing information to decision-makers at institutional and even national level, such as by identifying research patterns across faculties or universities. Furthermore, Owoc et al. (2021) indicated that the benefits of AI in education are the following: (a) automation of repetitive and time-consuming activities such as grading or controlling student attendance, (b) use of AI facilitators to support teachers in their classroom work, (c) feedback for teachers using AI chatbots to collect students' opinions, (d) adaptive

learning through customization according to each learner's needs, (e) spaced repetition and knowledge revision for students, and (f) AI-powered anti-cheating systems.

As Popenici and Kerr (2017) pointed out, AI is used every day in higher education campuses around the world. For example, universities have a wide array of data about students (i.e., academic, socioeconomic, and operational data) that can be analyzed to predict certain trends and identify patterns in students' behavior in real-time, which can give educators a more holistic insight into the status of their students. Using this data, AI can help in responding to individual users' needs for pacing and progress through personalized learning platforms.

Latin American higher education

Latin America is a region comprising 19 countries located in North, Central and South America that share similar histories, cultural and linguistic backgrounds. The region has a current population of approximately 617 million (The World Bank, 2021a). Except for Brazil, where Portuguese is the most widely spoken language, every Latin American country has a majority of Spanish speakers. According to the World Bank (2021a), the most populated countries in the region are Brazil (212.6 million) and Mexico (128.9 million), and the countries with the smallest populations are Uruguay (3.5 million) and Panama (4.3 million). The country with the highest number of students enrolled in higher education is again Brazil (8.7 million students), followed by Mexico (4.6 million) and Argentina (3.2 million). Only Brazil invests more than 1% of its GDP in research-related activities, with Argentina (0.61%), the highest of the other countries.

The gross enrollment rates in Latin American higher education institutions have increased from 21% in 2000 to 52% in 2018, and there are now approximately 28 million students enrolled in higher education across the region. Moreover, the majority of enrollments in many Latin American countries are in private institutions (The World Bank, 2021b). According to Brunner and Labraña (2020), higher education in Latin America has shifted toward massification and universalization after initially providing access only to the elite. Despite increased access to higher education, however, higher education systems in the region face several challenges, such as educational inequality, delays in graduation, and high dropout rates among students with low socioeconomic status (Balán, 2020). Nevertheless, Latin American higher education institutions have made efforts to increase their use of technological and digital educational tools to benefit not only students and teachers but also educational administrators.

Methodology

This article presents a systematic literature review of the current application of AI technology in higher education institutions in Latin America. A systematic review explores previous studies to answer specific research questions based on an explicit, systematic, and replicable search strategy, with inclusion and exclusion criteria (Kitchenham et al., 2009; Xiao & Watson, 2019). It is useful for understanding the work that has been done in a particular area through analyzing and synthesizing empirical evidence from previous studies to answer general research questions. Moreover, Twining et al. (2017) highlighted the importance of qualitative studies—regarding technologies applied in education—in understanding a situation or phenomenon through the identification

of themes and patterns in the data. Originally AI was the focus of computer scientists and engineers, but it has expanded to other disciplines where AI contributes developing novel applications such as health care, neuroscience, and psychology. Therefore, AI research can enhance the teaching–learning process when seeking to answer why and how a particular observed phenomenon occurs in the education field (Longo, 2020).

Therefore, given the recent emergence of relevant literature, a systematic review is appropriate for capturing information about the impact of AI applications on teaching and learning activities at higher education institutions in Latin America. The phases of a systematic review are: defining the research questions, conducting a literature search, screening relevant research articles, analytical coding and data extraction, and synthesizing the findings to shine light on trends, gaps, or contradictions. These phases are elaborated upon below.

Search strategy

Latin American scientific articles are usually published in Spanish or Portuguese. The largest repository in the region is Scielo, which indexes national and regional Latin American journals. Another important source is the CAPES Portal, which indexes high-quality Brazilian journals. In total, four databases were searched: Web of Science, IEEE Xplorer, Scielo, and CAPES Portal. These repositories were chosen as primary databases for their comprehensiveness and ease of use.

Relevant studies were identified with publication dates from July 2016 to June 2021, a 5-year period. The search was conducted in July 2021 by inserting a search string with the selected terms in each of the selected databases. A typical search string was ("artificial intelligence" OR "machine learning" OR "deep learning" OR "natural language processing" OR chatbot* OR "neural network*") AND ("higher education" OR "universit*"), plus the name of each Latin American country, with the search performed in English, Spanish, and Portuguese. The following inclusion criteria were used to select articles from the databases:

- Publication date from July 2016 to June 2021.
- Published in English, Spanish, or Portuguese.
- Published in a peer-reviewed journal or conference proceedings.
- Presenting empirical primary research.
- Including data relevant to AI applications in Latin American higher education institutions (with a focus on machine learning, deep learning, and natural language processing applications).

An initial search was carried out in the databases on titles, abstracts, and keywords, retrieving 2397 articles. The search was then refined based on the inclusion and exclusion criteria to ensure that the selected articles were able to answer the RQs. This reduced the number of potential papers to 401. After removing 18 duplicate papers, 383 articles remained. We screened the abstracts of these papers and removed 307 articles that were deemed not relevant, for example: conceptual papers, opinion pieces, other emergent technologies (e.g., virtual reality, augmented reality, 3D, EEG/ECG sensors, etc.), content in higher education but on fields such as agriculture, economics, medicine,

industrial applications, and so on. The 76 remaining articles were full-content screened, and a further 45 articles that did not fulfil the inclusion criteria were removed. Therefore, 31 published articles were finally selected for the analysis (see Fig. 1).

Data extraction and analysis

The data extraction involved collecting and coding information for each of the 31 studies, with the following information identified to help organize the data for analysis:

- Title, author/s, year of publication, country where the study took place.
- Education topic of the study.
- Common AI techniques (machine learning, deep learning, and natural language processing) used in the study.
- Common software tools and AI algorithms used in the study.
- AI application used in the study.

Fig. 1 Flow diagram of the article selection process
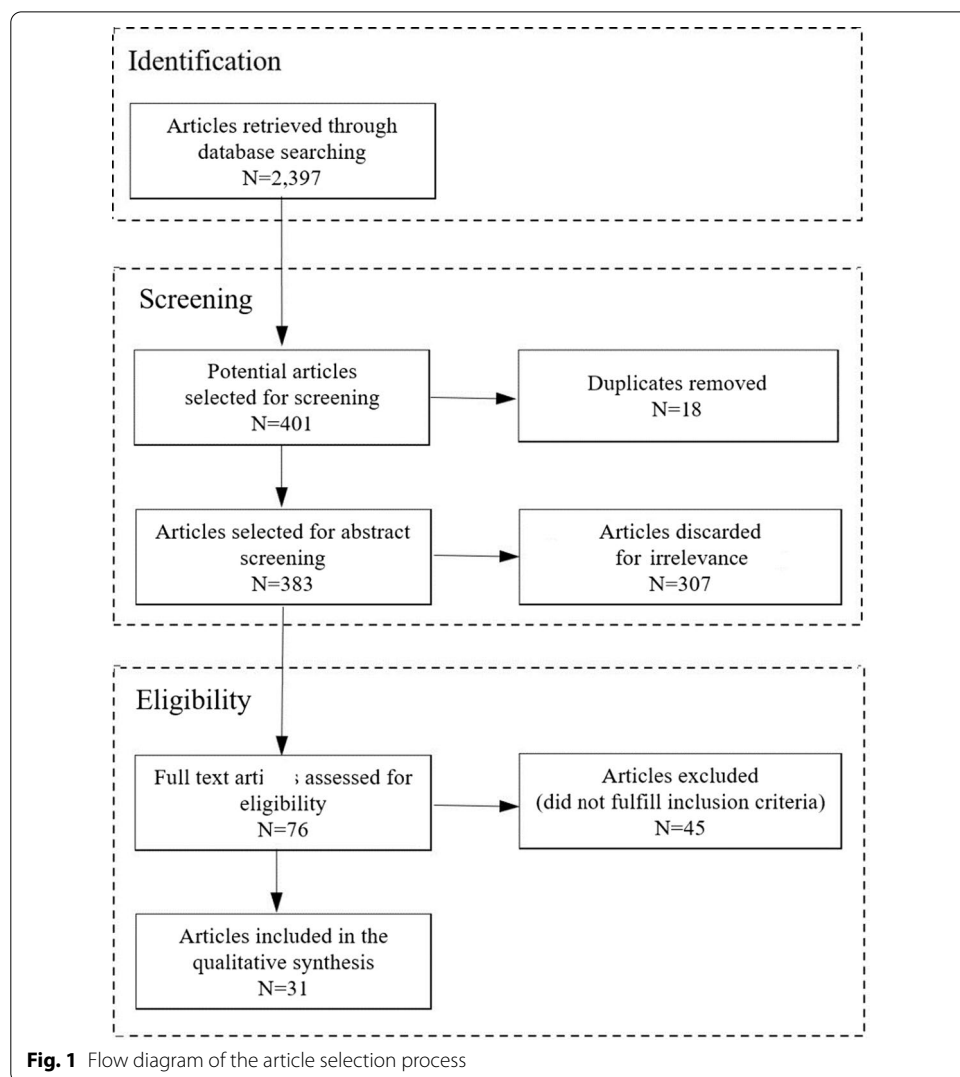
Results and discussion

The studies came from the following countries: seven from Mexico, seven from Colombia, six from Ecuador, five from Brazil, two from Peru, two from Chile, one from Argentina, and one from Bolivia (see Table 1).

AI applications in higher education

RQ1: What and how AI-based applications are being used by higher education institutions in Latin America?

Several AI applications have been implemented in higher education worldwide. However, in the Latin American context, these applications have particular characteristics. Table 2 presents a summary of the AI applications implemented in educational settings across the studies under review.

Predictive modeling in education

AI prediction models estimate educational processes using large educational datasets (Brooks & Thompson, 2017). Predictive modeling is beneficial because it gives accurate insight into educational questions and allows decisions to be made in advance; it is also time-saving and cost-effective. For example, AI applications can predict students' dropout rates (da Fonseca Silveira et al., 2019; Palacios et al., 2021), course performance (Bojorque & Pesántez-Avilés, 2020), and academic performance (Castrillón et al., 2020). Of the predictive models in the reviewed studies, the most common algorithm was the Multilayer Perceptron Artificial Neural Network (MLP-ANN), which also achieved a high average accuracy.

AI computer-assisted content analysis

The remarkable advances of AI have brought about the opportunity to automate the analysis of textual content. Whereas manual content analysis was typical some years ago, AI computer-assisted content analysis is now being adopted. The use of natural language processing brings many opportunities in areas that involve an immense amount of textual data (Lu, 2018). Regarding content analysis, the Latin American studies showed that AI algorithms have been applied in higher education for student online assessment (Mendoza Jurado, 2020), for extracting information from university documents to generate a dataset that can provide answers to queries (Sayama et al., 2019), and for evaluating teacher performance through student comments (Gutiérrez et al., 2018) or the analysis of syllabuses (Okoye et al., 2020).

Assistive technology (chatbots)

AI-based conversational agents, known as chatbots, are AI applications that can simulate a conversation using text or voice as input. These applications are being integrated in social networks, websites, and a variety of platforms (Borsci et al., 2021). Chatbots are used for a range of purposes in the education sector. For example, chatbots can be used to break down the barriers preventing young university students

Table 1 Summary of studies on AI application in higher education institutions in Latin America that met the inclusion criteria

ID	Author(s), year	Country	AI tecnique	Tools	Algorithms used	AI application	Education topic
[1]	Bedregal-Alpaca et al. (2020)	Peru	ML (Prediction)	JAVA, SPSS Modeler, SPSS Statistics, EXCEL	MLP, DT (ID3 & C4.5)	Predictive modelling in education	Dropout and retention
[2]	Bojorque and Pesántez-Avilés (2020)	Ecuador	ML (Prediction)	n.d.	MLP-ANN	Predictive modelling in education	Teaching performance
[3]	Castrillón et al. (2020)	Colombia	ML (Prediction)	WEKA	J48	Predictive modelling in education	Student performance
[4]	Chacón-Sánchez et al. (2020)	Colombia	ML (Classification)	WEKA	J48, J48Graft, NB, RT	Intelligent analytics	Student future development
[5]	Choque-Díaz et al. (2018)	Peru	NLP (Chatbot)	IBM Cloud platform, IBM Watson cognitive services	n.d.	Assistive technology (chatbots)	University services
[6]	Contreras et al. (2020)	Colombia	ML (Prediction)	Python	DT, SVM, MLP, KNN	Predictive modelling in education	Student performance
[7]	Cordero et al. (2020)	Ecuador	NLP (Chatbot)	Scrum, Extreme Programming (XP), IBM Watson™ Assistant	n.d.	Assistive technology (chatbots)	University services
[8]	da Fonseca Silveira et al. (2019)	Brazil	ML (Prediction)	Geocode, H2O AI, R	GLM, GBM, RF	Predictive modelling in education	Dropout and retention
[9]	Dehon et al. (2018)	Brazil	NLP (Chatbot)	LMS Moodle, Facebook Messenger chatbot, Facebook Notifier (Moodle plug-in)	n.d.	Assistive technology (chatbots)	Teacher-student communication
[10]	Delahoz-Domínguez et al. (2020)	Colombia	ML (Classification)	R	DT, RF	Intelligent analytics	University performance
[11]	Espinosa Rodríguez et al. (2018)	Mexico	NLP (Chatbot)	Facebook Messenger Chatbot, MongoDB mLAB	n.d.	Assistive technology (chatbots)	Student health and well-being
[12]	Fiallos et al. (2017)	Ecuador	NLP (Social Network Analysis)	n.d.	Force Atlas 2, TF-IDF model, LDA model	AI computer-assisted content analysis	University performance
[13]	García-González and Skrita (2019)	Colombia	ML (Prediction)	R	CT	Predictive modelling in education	Student performance

Table 1 (continued)

ID	Author(s), year	Country	AI tecnique	Tools	Algorithms used	AI application	Education topic
[14]	García-Vélez et al. (2019)	Ecuador	ML (Prediction)	scikit-learn toolkit	MLP	Predictive modelling in education	Student performance
[15]	Gómez Cravioto et al. (2020)	Mexico	ML (Prediction)	WEKA	J48, REPTree, RF	Predictive modelling in education	Student future development
[16]	Gutiérrez et al. (2018)	Mexico	ML & NLP (Sentiment Analysis)	R	SVM k-linear, k-radial, k-poly), RF	AI computer-assisted content analysis	Teaching performance
[17]	Klos et al. (2021)	Argentina	NLP (Chatbot)	Facebook Messenger Chatbot, SPSS	n.d.	Assistive technology (chatbots)	Student health and well-being
[18]	Mendoza Jurado (2020)	Bolivia	ML & NLP (Automatic review)	Python (Bag of Words), Tokenizer class from Keras (Python Deep Learning API)	NLP, MLP-ANN	AI computer-assisted content analysis	Assessment and evaluation
[19]	Menezes et al. (2020)	Brazil	DL (Facial recognition)	FaceNet architecture, Image capturing devices	HOG, CNN	Image analytics	Assessment and evaluation
[20]	Miranda and Guzmán (2017)	Chile	ML (Prediction)	SQL server, SPSS (MLP, DT), WEKA (BN)	MLP, DT, BN	Predictive modelling in education	Dropout and retention
[21]	Nieto et al. (2019)	Colombia	ML (Prediction)	KNIME	DT, RF, LR	Predictive modelling in education	University performance
[22]	Okoye et al. (2020)	Mexico	NLP (Sentiment Analysis)	R, Word Cloud	get_nrc_sentiment function get_senti-ment function	AI computer-assisted content analysis	Teaching performance
[23]	Palacios et al. (2021)	Chile	ML (Prediction)	WEKA	DT, KNN, LR, NB, RF, SVM	Predictive modelling in education	Dropout and retention
[24]	Sandoval-Palis et al. (2020)	Ecuador	DL (Prediction)	R, SPSS, Orange	MLP-ANN	Predictive modelling in education	Student performance
[25]	Santos et al. (2020)	Brazil	ML (Prediction)	Python	EvolveDTree (GA & DT), KNN, AdaBoost, SVC, MLP, RF, QDA, NB	Predictive modelling in education	Dropout and retention

Table 1 (continued)

ID	Author(s), year	Country	AI tecnique	Tools	Algorithms used	AI application	Education topic
[26]	Sayama et al. (2019)	Brazil	DL & NLP (Reading comprehension)	Python (Natural Language Toolkit), Python (Deep Learning AI)	BiDAF, NLTK library, Tensorflow library	AI computer-assisted content analysis	University services
[27]	Tapia-Leon et al. (2017)	Ecuador	NLP (Knowledge Extraction)	PSPP (free version of SPSS), Python (Natural Language Toolkit)	NLTK library	AI computer-assisted content analysis	Teaching performance
[28]	Torres Soto et al. (2019)	Mexico	DL (Prediction)	Python (libraries Keras and Tensorflow)	ANN	Predictive modelling in education	Student health and well-being
[29]	Ulloa Cazarez and López Martín (2018)	Mexico	ML (Prediction)	n.d.	RBF, MLP, GR	Predictive modelling in education	Student performance
[30]	Villaseñor et al. (2017)	Mexico	ML (Classification)	LabSOM system, Scientometric tools (SJCR and SIR)	Self-organizing Map (SOM) family of neural networks	Intelligent analytics	University performance
[31]	Visbal-Cadavid et al. (2019)	Colombia	ML (Prediction)	R (Caret & nnet packages)	MLP-ANN	Predictive modelling in education	University performance

AdaBoost adaptative boosting, *ANN* Artificial Neural Network, *BiDAF* Bi-Directional Attention Flow model, *BN* Bayesian Network, *CART* Classification and Regression Trees, *CNN* Convolutional Neural Networks, *CT* Classification Tree, *DL* deep learning, *DT* Decision Tree, *FA* Force Atlas Algorithm, *GA* genetic algorithms, *GBM* Gradient Boosting Machine, *GLM* Generalized Linear Model, *GR* general regression, *HOG* Histogram of Oriented Gradients, *KNN* k-nearest neighbors, *LDA* Latent Dirichlet Allocation model, *LR* logistic regression, *ML* machine learning, *MLP-ANN* Multilayer Perceptron Artificial Neural Network, *NB* Naïve Bayes, *NLP* Natural Language Processing, *NLTK* Natural Language Toolkit, *QDA* Quadratic Discriminant Analysis, *RBF* Radial Basis Function, *REPTree* Reduced Error Pruning Tree, *RF* Random Forest, *RT* Random Tree, *SOM* Self-organizing Map, *SVC* Support Vector Classifier, *SVM* Support Vector Machines, *TF-IDF* Frequency–Inverse Document Frequency Model

Table 2 AI applications in Latin America higher education across reviewed studies

AI application	Study ID	No. of studies
Predictive modelling in education	[1], [2], [3], [6], [8], [13], [14], [15], [20], [21], [23], [24], [25], [28], [29], [31]	16
AI computer-assisted content analysis	[12], [16], [18], [22], [26], [27]	6
Assistive technology (chatbots)	[5], [7], [9], [11], [17]	5
Intelligent analytics (classification)	[4], [10], [30]	3
Image analytics (facial recognition)	[19]	1

from sharing their personal concerns and behaviors, as well as to identify students that present symptoms of attention deficit hyperactivity disorder (Espinosa Rodríguez et al., 2018). Chatbots are also being used to detect anxiety and depressive symptoms in students and address delays associated with access to treatment (Klos et al., 2021).

Intelligent analytics (classification)

Intelligent analytics uses AI algorithms to process and prepare rich educational data for statistical analysis and to show evidence of the classification results (Sun & Stranieri, 2021). Higher education institutions in Latin America have used this AI application to identify the indicators of university graduates' employability (Chacón-Sánchez et al., 2020) and to analyze the impact of universities classified as accredited or non-accredited on student standardized tests, as accreditation is intended to ensure high quality education (Delahoz-Dominguez et al., 2020). Intelligent analytics can also help to evaluate academic research performance and scientific productivity (Villaseñor et al., 2017) where a classification process is used to understand and optimize higher education systems.

Image analytics (facial recognition)

Image analytics is an AI application that extracts, analyzes, and evaluates information from digital images through the use of AI algorithms. Its growth has been greatly facilitated by the explosion of digital image production and the ever-increasing quality and diversity of images. The most widely known application of AI for image analytics is facial recognition (Dzhangarov et al., 2020). In the education field, image analytics has been used to extract facial features and detect emotion. In Latin American higher education institutions, AI image analytics has been applied for managing student attendance using facial recognition with just one image from a capturing device (Menezes et al., 2020).

AI techniques, software tools, and algorithms used

RQ2: What are the common AI techniques, software tools, and AI algorithms used in Latin American high education?

AI techniques

Table 3 presents the AI techniques used in the reviewed studies. We found that 17 studies used machine learning, of which 14 focused on prediction and three on classification.

Table 3 AI techniques and the type of process used by the reviewed studies

AI technique	Type of process	Study ID	No. of studies	Total
ML	Prediction	[1], [2], [3], [6], [8], [13], [14], [15], [20], [21], [23], [25], [29], [31]	14	17
	Classification	[4], [10], [30]	3	
NLP	Chatbots	[5], [7], [9], [11], [17]	5	8
	Social network analysis	[12]	1	
	Sentiment analysis	[22]	1	
	Knowledge extraction	[27]	1	
DL	Prediction	[24], [28]	2	3
	Facial recognition	[19]	1	
ML & NLP	Sentiment analysis	[16]	1	2
	Automatic review	[18]	1	
DL & NLP	Reading comprehension	[26]	1	1

DL deep learning, *ML* machine learning, *NLP* natural learning processing

Table 4 AI software tools used by the reviewed studies

Main AI tools used	Study ID
R	[8], [10], [13], [16], [22], [24], [31]
Python	[6], [18], [25], [26], [27], [28]
SPSS	[1], [17], [20], [24]
WEKA	[3], [4], [15], [20], [23]
Facebook Messenger chatbot	[9], [11], [17]
LMS Moodle	[9]

Eight studies used natural language processing, of which five were on chatbots, one was on social network analysis, one was on reading comprehension, and one was on knowledge extraction. Three studies used deep learning techniques, of which two focused on prediction and one on facial recognition. A further three studies combined two techniques: two studies combined the approaches of machine learning and natural language processing for sentiment analysis and automatic review, and one study combined deep learning and natural learning processing for reading comprehension.

AI software tools

Table 4 summarizes the AI software tools used in the reviewed studies. The most frequently used software tools were the R and Python programming languages, SPSS, and WEKA (Waikato Environment for Knowledge Analysis); these were followed in popularity by the Facebook Messenger chatbot and LMS Moodle. Some of the other open-source software packages used were the H2O AI platform, the KNIME (Konstanz Information Miner) analytic platform, PSPP (a free version of SPSS), and Orange. Some of the studies used two or three tools simultaneously.

AI algorithms

Table 5 presents a summary of the main AI algorithms employed in the reviewed studies. The most frequently used AI algorithm was MLP-ANN (Multilayer Perceptron Artificial

Table 5 Most frequently used AI algorithms and their accuracy rates (%)

Study ID	DT	J48	KNN	LR	MLP	NB	RF	SVM
[1]					**66**			
[3]		**91.67**						
[4]		**62.7**				61.34		
[6]	55		55		61			**66.24**
[10]	90			88			**91**	
[14]					**81.5**			
[15]		69.9					**73.5**	
[17]							84.9	**85.2**
[18]					**94.4**			
[20]	72				**73**			
[21]	83.92			84.02			**84.11**	
[23]	82.19		83.93	83.45		79.14	**88**	83.97
[24]					**74.5**			
[25]	**99.38**		99.29		98.67	95.59	98.55	
[28]					**90**			
[31]					**90.28**			

Note. Text in bold indicates the highest accuracy level for each study

DT Decision Tree, *KNN* k-nearest neighbors, *LR* logistic regression, *ML* machine learning, *MLP-ANN* Multilayer Perceptron Artificial Neural Network, *NB* Naïve Bayes, *RF* Random Forest, *SVM* Support Vector Machines

Neural Network), followed by Random Forest (RF) and Decision Tree (DT). Other algorithms that were used in the studies were Naïve Bayes (NB), Support Vector Machine (SVM), Logistic Regression (LR), k-nearest neighbors (KNN), and J48. MLP-ANN and RF reported the highest accuracy across the studies. Some of the studies compared several algorithms to select the most accurate.

Education topics and issues

RQ3:   What education topics and issues are being addressed by AI applications in Latin American higher education institutions?

The education topics addressed in the studies are categorized into the three processes of education: learning, teaching, and administration. These educational processes are related to the three main higher education stakeholders: students, teachers, and educational authorities. Table 6 presents a synthesis of the reviewed studies according to education topic.

Learning (students)
Most of the studies focused on how to predict students' academic performance, mental health and well-being, and post-graduation development. These three topics are very important in Latin American higher educationinstitutions, and AI techniques are an alternative means for providing solutions and support to improve the quality of education.

Student performance Improving students' academic performance is crucial for higher education institutions (Helal et al., 2018) but is not an easy task because of the influence

Table 6 Education topic organized by educational process and major stakeholder

Educational process (stakeholder)	Education topic	Study ID	No. of studies	Total
Learning (student)	Student performance	[3], [6], [13], [14], [24], [29]	6	11
	Student health and well-being	[11], [17], [28]	3	
	Student future development	[4], [15]	2	
Teaching (teacher)	Teaching performance	[2], [16], [22], [27]	4	7
	Assessment and evaluation	[18], [19]	2	
	Teacher-student communication	[9]	1	
Administration (educational authority)	Dropout and retention	[1], [8], [20], [23], [25]	5	13
	University services	[5], [7], [26]	3	
	University performance	[10], [12], [21], [30], [31]	5	

of different personal, socioeconomical, and institutional factors. For this purpose, analyses by AI applications can provide interesting insights. For example, Castrillón et al. (2020) found that student performance was influenced by the academic factors of teacher pedagogy, appropriate schedules, the teacher–student relationship, teacher academic quality, and student internship experience. García-González and Skrita (2019) found that the most influential socioeconomic factors were the mother's education level, the socioeconomic status of the household, and the number of books in the household.

Student mental health and well-being As well-being is an important condition for academic achievement, preventing various health issues, such as depression, anxiety, or interpersonal difficulties, can be effective (Conley et al., 2017). Usually, affected students have to approach university services and request help. An alternative is the use of well-known AI applications called chatbots that can address mental health issues such as attention deficit hyperactivity disorder (Espinosa Rodríguez et al., 2018), identify suicidal tendencies (Torres Soto et al., 2019), and detect anxiety and depressive symptoms in university students (Klos et al., 2021) through user interactions.

Student post-graduation development After graduating, students have an expectation of employability; however, getting a job is difficult for many new graduates. The use of AI techniques to predict graduate employability has revealed the importance of providing guidance for graduates to build their careers, assessing quality in higher education provision (Bridgstock & Jackson, 2019), and researching the behavioral patterns of graduates (Chacón-Sánchez et al., 2020; Gómez Cravioto et al., 2020).

Teaching (teachers)

The diversity of educational topics found in the analysis indicates that AI could provide special support to teachers in time-consuming activities and to obtain fast and reliable data about their courses, teaching activities, and student evaluations.

Teaching performance The evaluation of teacher performance is always important in measuring the quality of education. However, such evaluations are highly complex (Gómez & Valdés, 2019). One alternative could be the use of AI applications to analyze students' comments and provide feedback to the teacher, suggesting improvements to the teaching and learning activities (Gutiérrez et al., 2018). Also, the amount of textual data generated by different educational activities means that AI can provide useful strategic insights for improvement of teaching and learning processes (Okoye et al., 2020),

to optimize and improve the monitoring of course performance (Bojorque & Pesántez-Avilés, 2020) and to extract relevant knowledge outlined on syllabuses while avoiding typical problems of manual processing (Tapia-Leon et al., 2017).

Assessment and evaluation Assessment is an ongoing process for learning and an essential part of formal higher education (Khairil & Mokshein, 2018). Online assessment could optimize results, reduce administrative time, promote immediate feedback, and increase the speeds of grading and student progress (Padayachee et al., 2018). This is especially true in the case of large student groups, for which these characteristics of online assessment provide multiple benefits. In this regard, AI technology can play a role in the automatic review of open questions (Mendoza Jurado, 2020) and in advanced technology of facial recognition for student attendance assessment (Menezes et al., 2020).

Teacher–student communication Higher education institutions are looking to make improvements in teacher–student communication because it can have a positive impact on the teaching and learning process (Erkan, 2019). One strategy could be to integrate chatbots in virtual LMS platforms to provide information about learning activities (Dehon et al., 2018).

Administration (educational authorities)

Many of the reviewed studies focused on the problems of students dropping out of university. Other administrative matters considered were university services and university performance in relation to research, accreditation, and governance.

Dropout and retention One of the main problems in higher education is the high student dropout rate, especially in undergraduate courses, and university reforms have been implemented to reduce the dropout rate (de Peña & Pérez, 2013). The problem persists, however, because of socioeconomic factors that affect academic achievement. In this context, AI applications can contribute to forecasting the student dropout rate and determining the factors that affect their performance (Bedregal-Alpaca et al., 2020; da Fonseca Silveira et al., 2019; Miranda & Guzmán, 2017; Santos et al., 2020). It can also identify at-risk students before they begin their studies (Palacios et al., 2021) so that they can be provided with greater attention and support to succeed in their academic studies.

University services University online services are now essential for interacting with students, teachers, and university staff on diverse academic and administrative activities. However, it can be time-consuming for university students to search for information on institutional websites, and it is therefore necessary to provide new communication channels that allow students to resolve their doubts or concerns about various matters at the university level (Dagli et al., 2020). AI-supported ways to address this issue could be to offer AI virtual assistants (chatbots) to enhance the online student experience (Choque-Díaz et al., 2018; Cordero et al., 2020) or to generate datasets containing information from the university's official documents **(**Sayama et al., 2019).

University performance (research, accreditation, governance) Generally, higher education institutions are intent on prioritizing the quality of their services, which strengthens the institutional duties of teaching and research and is reflected in the university's efficiency and performance (Artiukhov et al., 2021; Kumar, 2017). Interestingly, AI techniques can help to evaluate university performance (Visbal-Cadavid et al., 2019) and to

support the decision-making process at a strategic level through the timely compilation of the necessary data (Nieto et al., 2019). Meanwhile, accreditation is a benchmark of higher education performance. Under the new accreditation standards, Latin American universities must be prepared to achieve the best results in the accreditation process. To this end, AI applications can be used to analyze student academic results for university quality accreditation purposes (Delahoz-Dominguez et al., 2020). Research is another crucial issue for Latin American higher education institutions because in many advanced higher education systems, universities undertake research as their core mission alongside teaching. Moreover, research communities play a role in advancing a country's development. Therefore, the use of AI to detect scientific communities and prominent research areas can provide important information for policymakers as they look to set research priorities (Fiallos et al., 2017; Villaseñor et al., 2017).

Conclusions

This systematic review highlights the steps that have been taken to apply AI in Latin America higher education institutions. AI applications are gradually being adopted in different forms by higher education institutions in many Latin American countries, such as Brazil, Colombia, Mexico, Ecuador, Peru, Chile, and Argentina. However, the rate of AI adoption in education is still slow compared to that in other fields, such as medicine, industry, and finance. Castro et al. (2017) noted the importance of understanding the Latin American context when studying education in the region, with the main issues being ensuring access to higher education and student retention and graduation. Moreover, as Schwartzman (2020) mentioned, Latin American higher education is now facing new challenges in relation to technological advances that are changing the modes of knowledge creation and transmission; thus, there is still a need to promote awareness of the potential benefits of AI-based applications among the stakeholders of higher education institutions. The present study provides some evidence-based educational innovations through the application of AI technology in Latin America to address a range of higher education issues, such as increasing student performance, facilitating teachers' work, and supporting university services. The results demonstrate that AI is mainly being used for predictive modelling, intelligent analytics, assistive technology, automatic content analysis, and image analytics. As studies on AI are increasing and evolving, future research should keep a close eye on AI development in Latin America and include both content analysis and in-depth quantitative analysis of relevant studies.

One issue that emerged from this review is a lack of attention to ethics and data privacy. Few of the reviewed studies, in which Latin American researchers implemented AI technologies in the education sector, mentioned ethical clearance. It therefore seems there is still a need to establish protocols for personal data protection during educational data collection. As Siemens (2019) stated, there is a need for careful consideration of ethics and privacy in education research.

In summary, this review provides practitioners, researchers, and decision-makers with insights into diverse uses of AI in Latin American higher educationinstitutions. The main lessons learned are as follows: (a) Latin American researchers are helping to enhance the understanding of the potential of AI for educational innovation; (b) AI applications contribute to addressing a diverse range of learning, teaching, and administration issues

inside higher education institutions; (c) the recognition that AI applications can help to improve higher education quality. Finally, it is important that more educational stakeholders and decision-makers become involved and understand the benefits that AI technologies could bring to the Latin American higher education system.

Declarations

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