Techniques and applications of Machine Learning and Artificial Intelligence in education: a systematic review

Técnicas y aplicaciones del Machine Learning e Inteligencia Artificial en educación: una revisión sistemática

Wiston Forero-Corba - *Universitat de les Illes Balears, UIB (Spain)*
Francisca Negre Bennasar - *Universitat de les Illes Balears, UIB (Spain)*

ABSTRACT

Machine learning is a field of artificial intelligence that is impacting lately in all areas of knowledge. The areas of social sciences, especially education, are no stranger to it, so, a systematic review of the literature on the techniques and applications of machine learning and artificial intelligence in Education is performed. The lack of knowledge and skills of educators in machine learning and artificial intelligence limits the optimal implementation of these technologies in education. The objective of this research is to identify opportunities for improving teaching-learning processes and educational management at all levels of the educational context through the application of machine learning and artificial intelligence. The databases used for the bibliographic search were Web of Science and Scopus and the methodology applied is based on the PRISMA statement for obtaining and analyzing 55 articles published in high impact journals between the years 2021-2023. The results showed that the studies addressed a total of 33 machine learning and artificial intelligence techniques and multiple applications that were implemented in educational contexts at primary, secondary and higher education levels in 38 countries. The conclusions showed the strong impact of the use of machine learning and artificial intelligence. This impact is reflected in the use of different intelligent techniques in educational contexts and the increase of research in secondary schools on artificial intelligence.

Keywords: machine learning; artificial intelligence; educational innovation; emerging technology; educational revolution.

RESUMEN

El *Machine Learning* es un campo de la inteligencia artificial que está impactando últimamente en todas las áreas del conocimiento. Las áreas de las ciencias sociales, en especial la educación, no es ajena a ella, por tanto, se realiza una revisión sistemática de la literatura sobre aquellas técnicas y aplicaciones del *Machine Learning* e inteligencia artificial en Educación. La falta de conocimientos y habilidades de los educadores en *Machine Learning* e inteligencia artificial limita la implementación óptima de estas tecnologías en la educación. El objetivo de este trabajo es identificar las oportunidades de mejora de los procesos de enseñanza-aprendizaje y la gestión educativa en todos los niveles del contexto educativo a través de la aplicación de *Machine Learning* e inteligencia artificial. Las bases de datos utilizadas para la búsqueda bibliográfica fueron *Web of Science* y Scopus, la metodología aplicada se basó en la declaración PRISMA para la obtención y análisis de 55 artículos publicados en revistas de alto impacto entre los años 2021 y 2023. Los resultados mostraron que los estudios trataron un total de 33 técnicas de *Machine Learning* e inteligencia artificial y múltiples aplicaciones que fueron implementadas en contextos educativos en niveles de educación primaria, secundaria y superior en 38 países. Las conclusiones mostraron el fuerte impacto que tiene el uso de *Machine Learning* e inteligencia artificial. Este impacto se ve reflejado en el uso de diferentes técnicas inteligentes en contextos educativos y el aumento de investigaciones en escuelas de secundaria sobre inteligencia artificial.

Palabras clave: machine learning; inteligencia artificial; innovación educativa; tecnología emergente; revolución educativa.

How to cite: Forero-Corba, W., & Negre Bennasar, F. (2024). Techniques and applications of Machine Learning and Artificial Intelligence in education: a systematic review. [Técnicas y aplicaciones del Machine Learning e Inteligencia Artificial en educación: una revisión sistemática]. *RIED-Revista Iberoamericana de Educación a Distancia, 27*(1), 209-253. https://doi.org/10.5944/ried.27.1.37491

INTRODUCTION

Machine Learning (ML) is a branch of artificial intelligence (AI) that has seen an exponential increase in recent years. The scientific community is paying increasing attention to educational tools enriched with smart technology, as they have the potential to revolutionize teaching-learning processes.

At present, ML research applied to education in areas such as teacher perception (Salas Rueda et al., 2022), student perception (Demir & Güraksın, 2022), academic performance (Ahajjam et al., 2022), school dropout (Alvarado Uribe et al., 2022) and computational thinking (Almeida Pereira Abar et al., 2021), among others, show in their results, the implication of the use of intelligent techniques in the solution of complex problems in the education sector.

Different types of research have been compiled in systematic reviews on AI (Zawacki-Richter et al., 2019; Zhai et al., 2021; Salas-Pilco & Yang, 2022; Su et al., 2022) and systematic reviews on ML (Sasmita & Mulyanti, 2020; Luan & Tsai, 2021; Mittal et al., 2022). Reviews on AI have mainly focused on the university sector, with the exception of Su et al. (2022) which studies the primary school and high school levels. ML reviews have identified common keywords in research, such as prediction, identification, performance, and recommendation, and have described the type of intelligent algorithms or techniques used. Although these systematic reviews were conducted during or after the pandemic, only the study by Mittal et al. (2022) addressed COVID-19.

In education, the difference between ML and AI is not always clear, even though both fields focus on applying the concept of prediction. ML is focused on systems learning from data (Luan & Tsai, 2021), while AI allows systems to perform tasks autonomously (Zhai et al., 2021). However, our systematic review departs from analyzing studies of both AI and ML applied to the education sector for the following reasons: AI and ML aim to create systems that can execute tasks that are normally considered human-like, both fields use mathematical and statistical techniques to analyze and process data, they have great potential to revolutionize the way we interact with the world, and finally, the period from 2021 to February 2023 has experienced an exponential growth in research related to this topic.

In recent years, ML has provided different techniques or algorithms to predict situations according to large amounts of information that, through good data processing and filtering, can generate very effective predictions. Different authors have developed ML algorithms to help educators (Duzhin & Gustafsson, 2018; Yu et al., 2022). This has allowed these intelligent techniques to be applied to the education sector and to help combat the dynamic problems that afflict all types of contexts.

AI in schools offers multiple possibilities for school administrators, teachers, and students. One example is ChatGPT, the latest version, GPT-4, is integrated into software such as Microsoft Office, Edge, and Bing, optimizing educational tasks. AI and ML have been oriented towards educational tasks (Zafari et al., 2021), which highlights the need to strengthen Teachers' Digital Competence (TDC).

Continually, research in the education sector seeks to close educational gaps, and ML and AI emerge as an alternative means to achieve optimal results. A study of robotics with intelligent techniques aims to close the gap between educational and professional robotics by introducing ML techniques where differences in access, trajectory, progress and educational outcomes are best for students (Dietz et al., 2022). In addition to research in education, technological advancement is an important factor

for the education gap. Technological development has opened the gap to challenges in understanding the use, application, and inner workings of technologies, especially emerging technologies such as AI and ML (Temitayo et al., 2022). This indicates its importance as an emerging technology based on its correct use and application for the benefit of quality and dignified education.

The current curricula are constantly updated and with that in mind, curriculum development, which must provide answers to the demands imposed by the knowledge society, must include topics and activities based on ML and AI at all school levels, allowing to dynamize the teaching-learning processes. However, the complexity and dynamics of AI teaching highlight the need for a detailed examination of the curriculum development process in a given context (Dai et al., 2022), showing the relevance of curriculum assessment in all instructional areas and how to approach them according to the context.

Educational processes along with these intelligent techniques and tools applied in and out of the classroom have led to their implementation being treated with restraint due to the ethical considerations involved (Bogina et al., 2022). So much so, that teachers need to be trained and updated to cope with the teaching processes, improving their competences in communication, research, pedagogy, technology, and management, among others. As referred to by UNESCO (2019) in the Beijing Council on AI and education, education sectors must address the integration of the TDC on AI in ICT competency frameworks, to support the teachers training in educational environments with a strong presence of AI.

The inclusion of ML in education has made digital transformation of great benefit to all educational actors, making the education system more convenient for both teachers and students (Nafea, 2018). However, it would also be of great benefit to school administrators and families, who are an important reference point in any educational community and are closely involved in the benefits that these new technologies can generate.

The training of teachers in AI and ML is a challenge for educational institutions. For digital transformation in the classroom to become a reality, teachers must be prepared to adapt technology to their teaching practices (Almeida Pereira Abar et al., 2021), which requires solid knowledge in these areas. Lack of such knowledge limits the optimal implementation of AI and ML technologies in education. As such, school administrators need to take on the challenge of leading the training of the TDC.

The aim of this research is to identify opportunities for improving teaching-learning processes and educational management at all levels of the educational context through the application of machine learning and artificial intelligence.

On this basis, this paper answers the following research questions (RQ):

RQ1: What levels of education have ML or AI studies been conducted in education?
RQ2: In which countries has ML or AI research in Education been conducted and which country has the most influence?
RQ3: What are the key issues and the most frequent words used in the studies?
RQ4: What ML techniques have been used in research?
RQ5: What were the results of implementing ML or AI as an emerging technology in education?

METHODOLOGY

The methodology considered appropriate for ascertaining the current status of all types of research is the systematic review (Marín, 2022), following the PRISMA 2020 protocol (Yepes-Nuñez et al., 2021). The search equation (Table 1) was applied to obtain the studies in the Web of Science (WoS) and Scopus databases. From the inclusion and exclusion criteria for the filtering and narrowing of studies applied (Table 2), a group of 55 articles could be systematically obtained (Table 3).

Table 1 shows the search equation according to subject, educational approach, context, and level. For the document search in both databases, this equation is applied to the title, abstract and keywords. In WoS, "TS" is applied to the equivalent formula (title, abstract, and keywords) and in Scopus, the equivalent of "TITLE-ABS- KEY". The design of the search terms as well as the inclusion and exclusion criteria (Figure 1) are based on the recommendations by Zawacki-Richter et al. (2020), for systematic reviews focused on educational research, as well as the indications from Marín (2022) for educational technology research.

The search formula was as follows:

Table 1
Search equation

Topic	Search terms
Subject	*("machine learning") OR ("artificial intelligence")*
Educational approach	*("education") OR ("teach*") OR ("tutor*") OR ("educational*") OR ("pedagog*")*
Context	*("school*") OR ("universit*")*
Level	*("kindergarten") OR ("elementary school*") OR ("primary school*") OR ("middle school*") OR ("secundary school*") OR ("Bachelor*") OR ("high* school*") OR ("master*") OR ("doctora*")*

Source: own elaboration.

The inclusion and exclusion criteria are as follows:

Table 2
Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Published between 2021 to February 2023	Published before 2021
English	Not in English
Indexed in Web of Science or Scopus	Not indexed in Web of Science or Scopus
Publications related to education	Non-education publications
No systematic reviews	Systematic reviews
Open access	Not open access

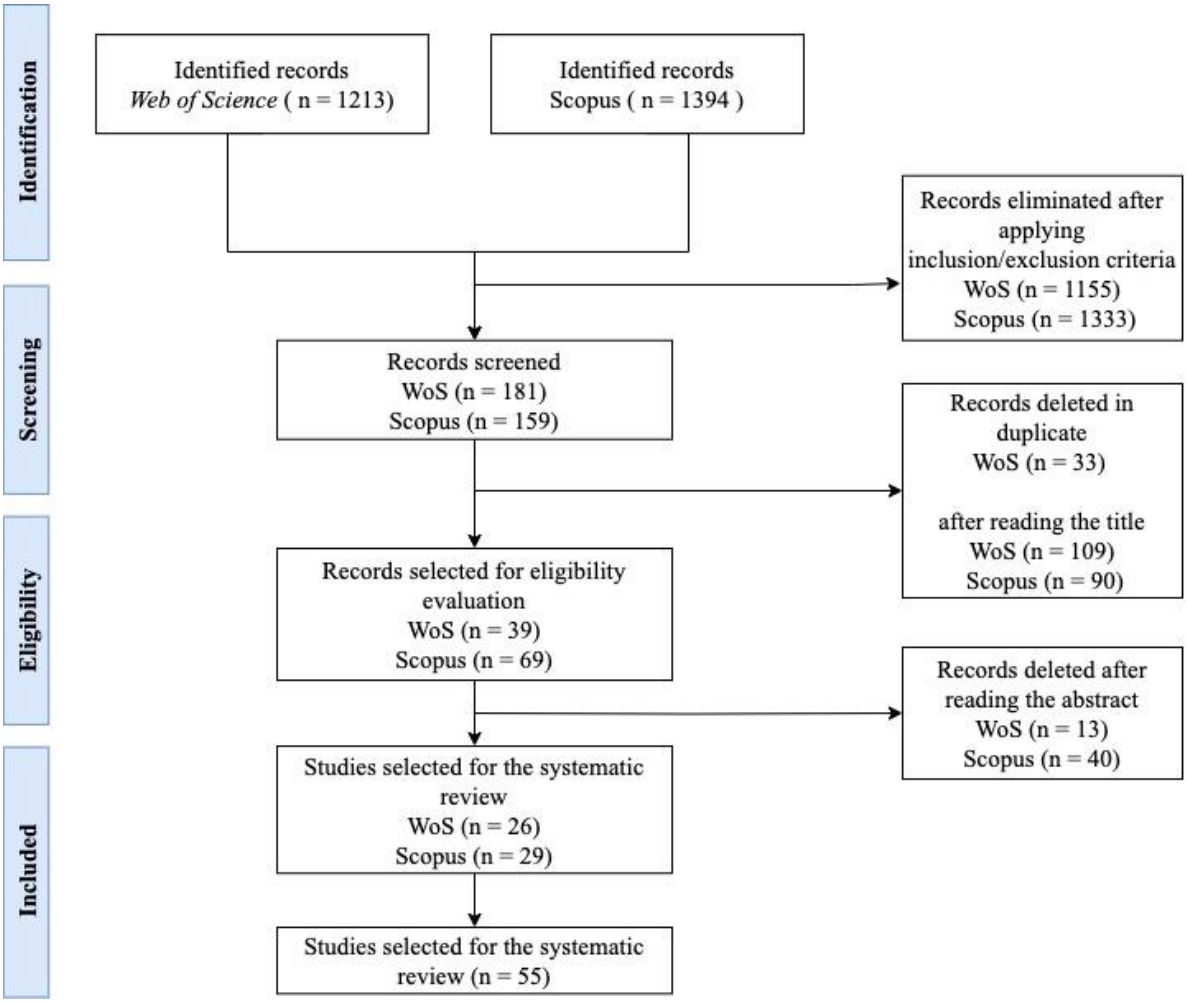
Source: own elaboration.

Considering Table 2, the studies were taken between 2021 and 2023 to reflect the latest advances in scientific knowledge. This research was done during and after the pandemic. In previous systematic reviews (Sasmita & Mulyanti, 2020; Su et al., 2022),

the selection of studies was limited to the English language. This is because most high-impact journals publish their articles in English, which is why we selected studies in English for our review. This allowed us to obtain studies relevant to our research. Databases are limited to WoS and Scopus as they are valued as the two most relevant bibliometric tools, being considered the two leading databases of academic articles in the world ranking (Zhu & Liu, 2020), allowing the identification of quality studies. To identify the latest research in the area, follow trends and research relevance, the WoS *Core Collection* database was used.

Figure 1 shows the entire procedure with all inclusion and exclusion criteria.

Figure 1
PRISMA Flowchart of the study



Source: own elaboration.

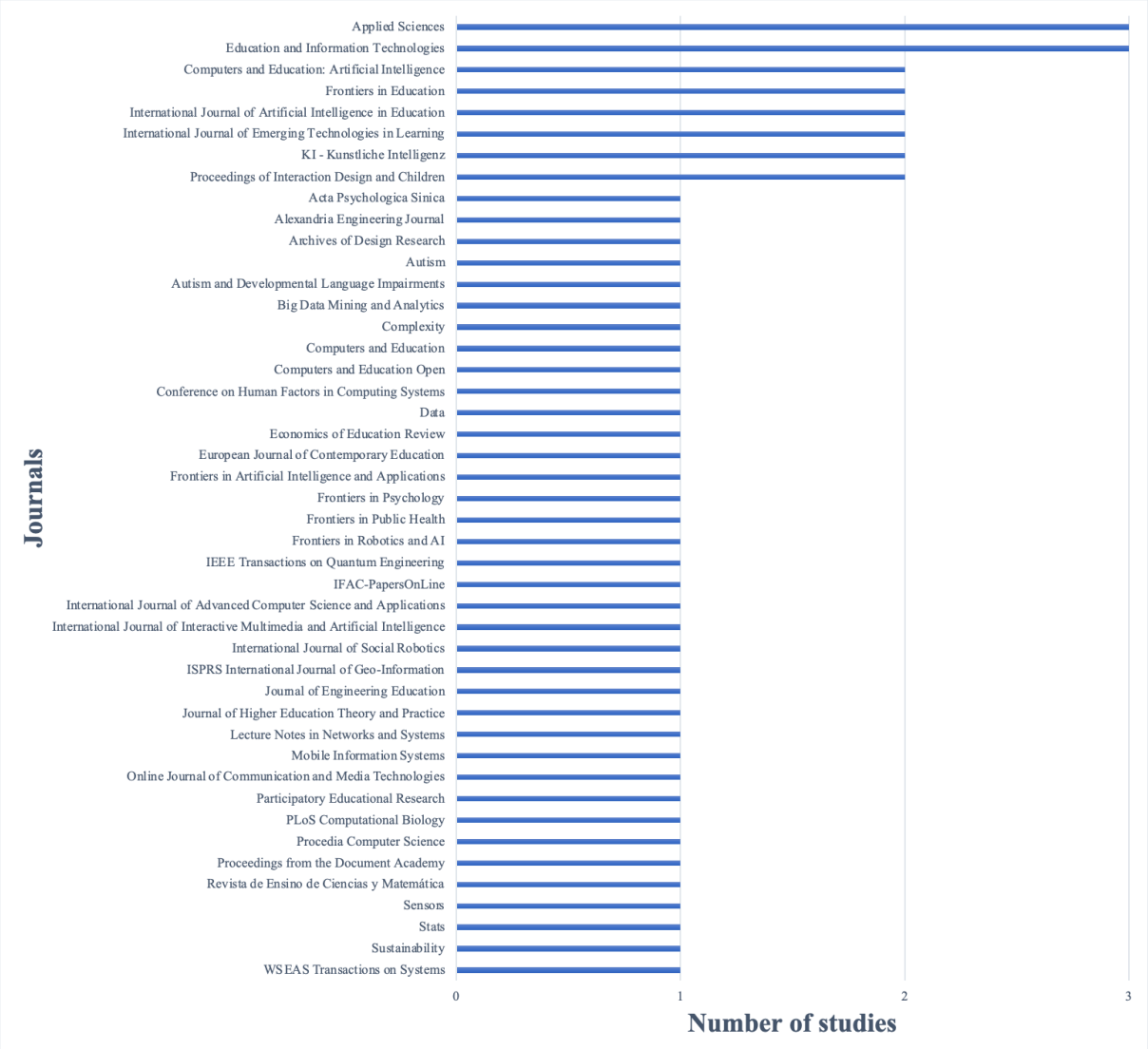
The two researchers were involved in the screening, jointly reviewing the studies up to the results. For the systematic review, the *Rayyan* tool was used, which allowed coding data on the year of publication, journal name, countries of authorship, sample, methodology and results. The socialization of the sample, methodology and results of each study was necessary to unify criteria and guarantee the quality of the research.

The documentary analysis was carried out using descriptive statistics and systematic content analysis. *Orange Data Mining 3.35.0* software was used to perform the geographical location of the studies, the word cloud was used to analyze the top 20 most frequent words in the selected full papers. In addition, *VOSviewer 1.6.19* was used for the network map, *Microsoft Excel* for the statistical graphs and *app.diagrams.net* for the classification of ML techniques.

RESULTS

The results of the 55 articles below were drawn from 45 high-impact journals, as shown in Figure 2. The number of journals analyzed is an indicator that the study was comprehensive, covering a wide range of perspectives, trends, and patterns.

Figure 2
Journals vs Number of studies/journal



Source: own elaboration.

The journals with the highest number of studies in the review were Applied Sciences and Education and Information Technologies with 3 articles each. The significance of having 45 different journals out of 55 in the review increases the likelihood that a wider range of studies will be included and therefore be more representative of the available evidence.

Table 3 presents the studies selected in this review, specifying the title, central subject, context of application, country, or countries in which the research was implemented, whether it covered the COVID-19 topic, educational level, or levels at which the study was applied and the year of publication. (P: Primary), 2. (P, S: Primary, Secondary), 3. (S: Secondary), 4. (S, U: Secondary, University) 5. (U: University).

Table 3
Selected studies

Nº	Title	Central subject	Country	COVID 19	Educational level	Year
1	Automatic Detection of Gaze and Body Orientation in Elementary School Classrooms	Orientation of teachers and students in the classroom	Chile	NO	P	2021
2	Collaborative construction of artificial intelligence curriculum in primary schools	AI Curriculum	China	YES	P	2022
3	Computational Thinking in Elementary School in the Age of Artificial Intelligence: Where is the Teacher?	Computational thinking	Brazil, Portugal, Cape Verde, and Angola	NO	P	2021
4	Identifying Functions and Behaviours of Social Robots for In-Class Learning Activities: Teachers' Perspective	Social robotics	Canada	NO	P	2022
5	Shyness prediction and language style model construction of elementary school students	Predicting shyness	China	NO	P	2021
6	A machine learning approximation of the 2015 Portuguese high school student grades: A hybrid approach	Academic performance	Portugal	NO	P, S	2021
7	Sentiment analysis of Arabic tweets regarding distance learning in Saudi Arabia during the covid-19 pandemic	Distance learning	Saudi Arabia	YES	P, S	2021
8	"Alexa, Can I Program You?": Student Perceptions of Conversational Artificial Intelligence Before and After Programming Alexa	Student perception	United States	NO	S	2021

Nº	Title	Central subject	Country	COVID 19	Educational level	Year
9	A Practical Model for the Evaluation of High School Student Performance Based on Machine Learning	Academic performance	Iran	NO	S	2021
10	AI Curriculum for European High Schools: An Embedded Intelligence Approach	AI Curriculum	Lithuania, Finlandia, Slovenia, Italy, and Spain	NO	S	2022
11	An Education Tool at Supports Junior Learners in Studying Machine Learning	Teaching AI	Japan	NO	S	2022
12	An Effective Decision-Making Support for Student Academic Path Selection using Machine Learning	Academic guidance	Benin	NO	S	2022
13	Artificial Intelligence and Machine Learning to Predict Student Performance during the COVID-19	Academic performance	Morocco	YES	S	2021
14	ARtonomous: Introducing Middle School Students to Reinforcement Learning Through Virtual Robotics	Virtual robotics	United States	YES	S	2022
15	Children as creators, thinkers and citizens in an AI-driven future	Generative models	United States	NO	P, S	2021
16	Computer or teacher: Who predicts dropout best?	School dropout	Netherlands	NO	S	2022
17	Contextualizing AI Education for K-12 Students to Enhance Their Learning of AI Literacy Through Culturally Responsive Approaches	AI Curriculum	Japan	YES	P, S	2021
18	Determining middle school students' perceptions of the concept of artificial intelligence: A metaphor analysis	Perception AI	Turkey	NO	S	2022
19	Early Introduction of AI in Spanish Middle Schools. A Motivational Study	AI Curriculum	Spin	NO	S	2021
20	Exploring generative models with middle school students	Generative models	United States	NO	S	2021
21	Exploring teachers' preconceptions of teaching machine learning in high school: A preliminary insight from Africa	Teaching ML	Nigeria, Ghana, Tanzania, Kenya, South Africa, and Namibia	NO	S	2022

Nº	Title	Central subject	Country	COVID 19	Educational level	Year
22	Formation of the Optimal Load of High School Students Using a Genetic Algorithm and a Neural Network	School efficiency	Russia	NO	S	2021
23	From high school to postsecondary education, training, and employment: Predicting outcomes for young adults with autism spectrum disorder	ASD in Education with ML	United States	NO	S	2022
24	Graph Neural Network for Senior High Student's Grade Prediction	Academic performance	China	NO	S	2022
25	Identifying supportive student factors for mindset interventions: A two-model machine learning approach	Mindset intervention	United States	NO	S	2021
26	Improvement and Optimization of Feature Selection Algorithm in Swarm Intelligence Algorithm Based on Complexity	Teaching AI	China	NO	S	2021
27	Interdisciplinary K-12 Control Education in Biomedical and Public Health Applications	Virtual Reality in Health	United States	YES	P, S	2022
28	Learning Time Acceleration in Support Vector Regression: A Case Study in Educational Data Mining	Computational efficiency	Brazil	NO	S	2021
29	Modeling English teachers' behavioral intention to use artificial intelligence in middle schools	Teaching AI	China	NO	S	2022
30	Nurturing diversity and inclusion in AI in Biomedicine through a virtual summer program for high school students	Teaching AI	United States	YES	S	2022
31	Predicting Students' Final Performance Using Artificial Neural Networks	Academic performance	Morocco	NO	S	2022
32	Prediction of differential performance between advanced placement exam scores and class grades using machine learning	Academic performance	United States	NO	S	2022
33	Situation and Proposals for Implementing Artificial Intelligence-based Instructional Technology in Vietnamese Secondary Schools	Teaching AI	Vietnam	NO	S	2022

Nº	Title	Central subject	Country	COVID 19	Educational level	Year
34	Stem education-career pathway for emerging forensic analytics: Innovative professional development in multimodal environments	STEM for forensic analysis	United States	YES	S	2021
35	Teachers' readiness and intention to teach artificial intelligence in schools	Teaching AI	Nigeria	NO	S	2022
36	Teaching Quantum Computing to High-School-Aged Youth: A Hands-On Approach	Teaching quantum computing	Canada and United States	NO	S	2022
37	The application of artificial intelligence assistant to deep learning in teachers' teaching and students' learning processes	Learning processes	China	NO	S	2022
38	The Effect of Design Classes Using Artificial Intelligence in the Era of COVID-19 on Social Responsibility of High School Students	Social responsibility	South Korea	YES	S	2022
39	Understanding the response to financial and non-financial incentives in education: Field experimental evidence using high-stakes assessments	Economy	England	NO	S	2021
40	Urban-Rural Gradients Predict Educational Gaps: Evidence from a Machine Learning Approach Involving Academic Performance and Impervious Surfaces in Ecuador	Academic performance	Ecuador	NO	S	2021
41	Wearable Artificial Intelligence for Assessing Physical Activity in High School Children	Physical activity	Qatar	NO	S	2023
42	AI-Based Metaverse Technologies Advancement Impact on Higher education Learners	Metaverse	India	NO	S, U	2022
43	Erwhi Hedgehog: A New Learning Platform for Mobile Robotics	Robotics	Italy	NO	S, U	2021
44	Digital Transformation of Legal education: Problems, Risks and Prospects	Legal framework in Digital Education	Russia	NO	U	2021
45	Educating Software and AI Stakeholders About Algorithmic Fairness, Accountability, Transparency and Ethics	FATE	Israel and Spain	NO	U	2022

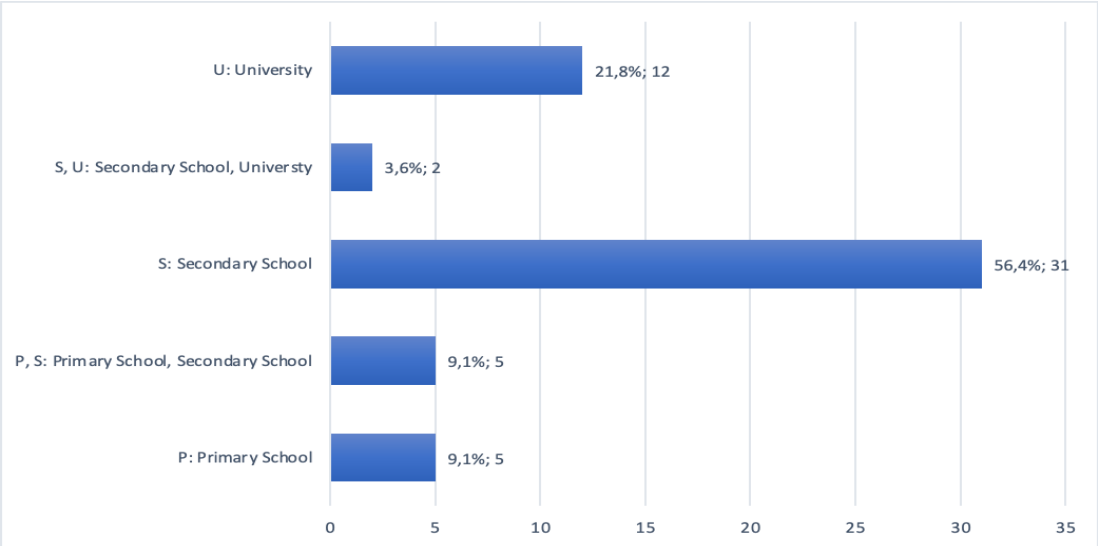
Nº	Title	Central subject	Country	COVID 19	Educational level	Year
46	Evaluating the user's experience, adaptivity and learning outcomes of a fuzzy-based intelligent tutoring system for computer programming for academic students in Greece	Intelligent tutor	Greece	NO	U	2022
47	Evaluation of postgraduate academic performance using artificial intelligence models	Academic performance	Malaysia	NO	U	2022
48	Machine Learning in Clinical Psychology and Psychotherapy Education: A Mixed Methods Pilot Survey of Postgraduate Students at a Swiss University	ML in clinical education	Switzerland	YES	U	2021
49	Modeling deception: A case study of email phishing	Phishing	United States	NO	U	2021
50	Online English Teaching Based on Artificial Intelligence Internet Technology Embedded System	Teaching AI	China	NO	U	2021
51	Predicting academic success of autistic students in higher education	School dropout ASD	Netherlands	NO	U	2023
52	Student Dataset from Tecnológico de Monterrey in Mexico to Predict Dropout in Higher Education	School dropout	Mexico	NO	U	2022
53	Teachers' Opinion About Collaborative Virtual Walls and Massive Open Online Course During the COVID-19 Pandemic	Teacher perception	Mexico	YES	U	2022
54	Towards the Grade's Prediction. A Study of Different Machine Learning Approaches to Predict Grades from Student Interaction Data	Academic performance	Spain	NO	U	2022
55	Using Recommender Systems for Matching Students with Suitable Specialization: An Exploratory Study at King Abdulaziz University	Recommendation of studies	Saudi Arabia	NO	U	2021

Note: P: Primary school, S: Secondary school, U: University, ASD: Autism Spectrum Disorder, FATE: fairness, accountability, transparency and ethics, STEM: Science, Technology, Engineering and Mathematics

To answer the first research question, based on Table 3, Figure 3 shows the level of education applied in the studies.

RQ1: What levels of education have ML or AI studies been conducted in education?

Figure 3
Educational level applied in studies

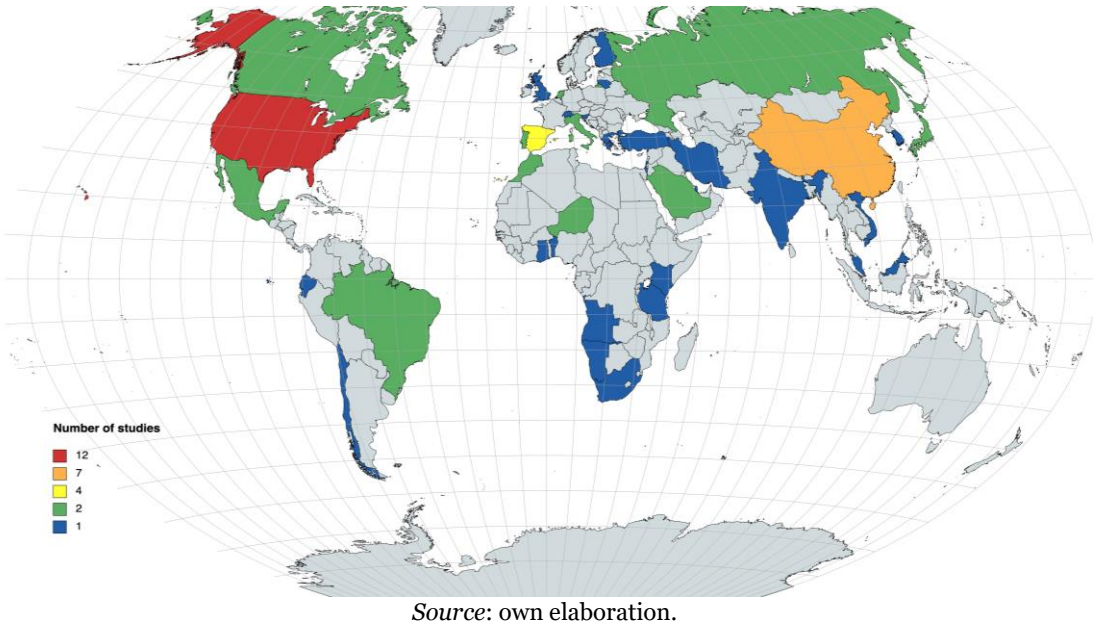


Source: own elaboration.

To answer the second research question, it is noted that studies in English often do not reflect the diversity of global research. Therefore, the choice was made to select research papers in English and to analyze how non-English speaking countries can base their studies in English to have a wider research reach. Figure 4 shows the geographical location (countries) in which the research was conducted and/or applied.

RQ2: In which countries has ML or AI research in Education been conducted and which country has the most influence?

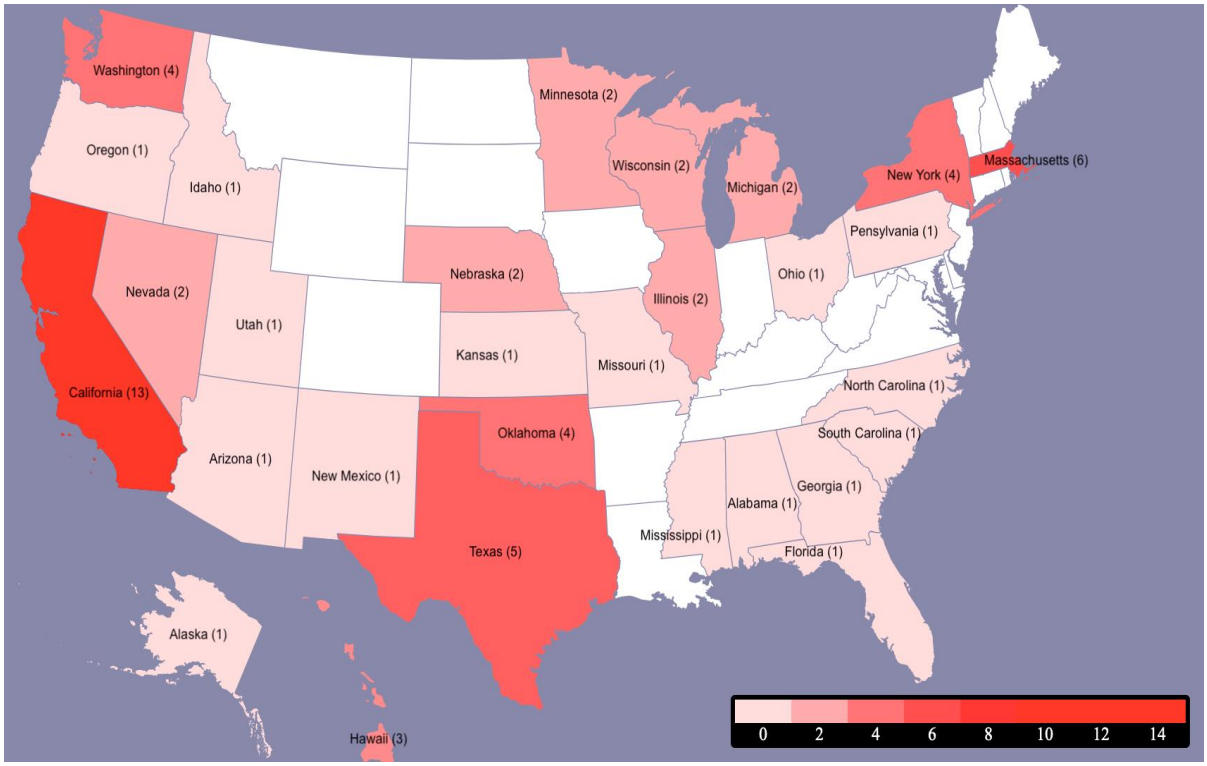
Figure 4
Geographical location of the studies



Source: own elaboration.

Figure 4 shows that the United States (USA) has the largest number of studies. Therefore, Figure 5 estimates the states with the highest research influence in the articles.

Figure 5
Influence of articles on USA



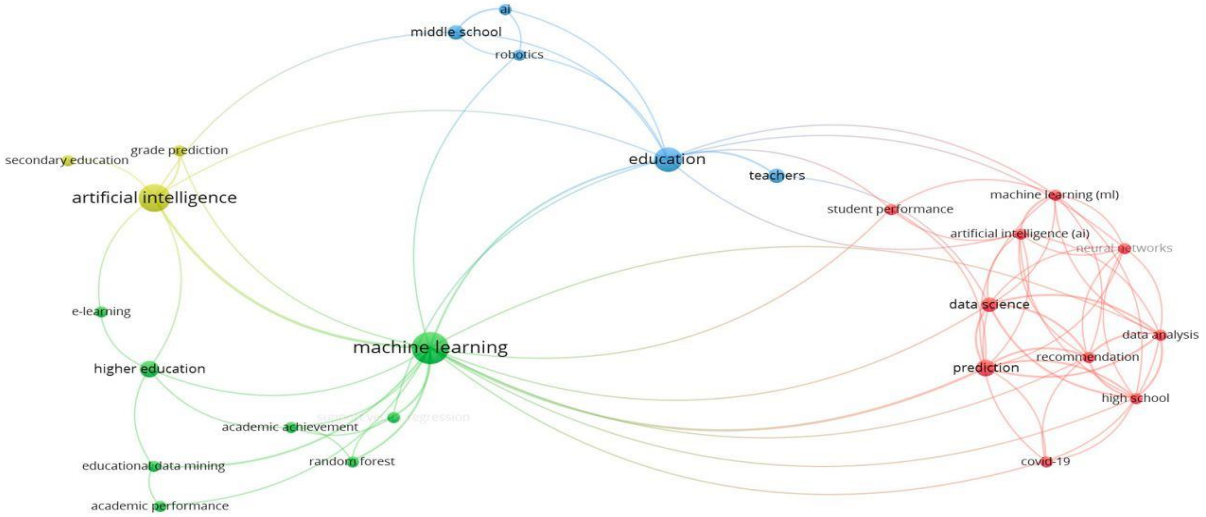
Source: own elaboration.

To answer the third research question, Figure 6 shows a network map depicting the relationships between the key subjects of the selected studies, and Figure 7 shows a word cloudhighlighting the 90 most frequent and relevant words in these studies.

RQ3: What are the key issues and the most frequent words used in the studies?

Figure 6 shows a network map representing the key subjects from the titles and abstracts of the 55 research papers. The network map shows four subclusters of interrelated key subjects, identified by colors: green for machine learning (ML), yellow for artificial intelligence (AI), blue for education and red for prediction.

Figure 6
Network map of the 55 research projects on ML and AI in Education



Source: own elaboration.

The green ML sub-cluster is connected to the yellow sub-cluster representing the AI theme because it is a key piece of technology for creating intelligent tools from data recognition and learning. On the other hand, the red sub-cluster representing the key subject of prediction is connected to the ML sub-cluster because ML techniques or algorithms are based on predictionfor decision making. Finally, both the ML and AI sub-cluster are connected to the blue sub-cluster representing the education subject, because it has the potential to improve the teaching-learning process in several ways, such as focusing on improving teacher skills, predicting, and identifying students' strengths and weaknesses to estimate their academic progress, supportingfields such as educational robotics and augmented reality, among others.

Figure 7
Word cloud representing the most frequent words

Source: own elaboration.

To quantitatively establish the *ranking of the* word cloud, Table 4 shows the 20 most frequent words in our word cloud. According to the *ranking*, the words "*students*", "*learning*" and "*ai*" (abbreviation for artificial intelligence) are the three most frequent words, indicating that the selected studies have a high ratio of application of smart tools in education.

Table 4
Most frequent words in studies

Ranking	**Word**	**Frequency**
1	*students*	3628
2	*learning*	2380
3	*ai*	2034
4	*education*	1870
5	*data*	1631
6	*school*	1600
7	*teachers*	1184
8	*student*	1175
9	*high*	1088
10	*model*	1012
11	*research*	958
12	*machine*	910
13	*study*	878
14	*teaching*	825
15	*educational*	694
16	*intelligence*	689
17	*performance*	657
18	*information*	639
19	*models*	619
20	*technology*	601

Source: own elaboration.

RQ4: What ML techniques have been used in research?

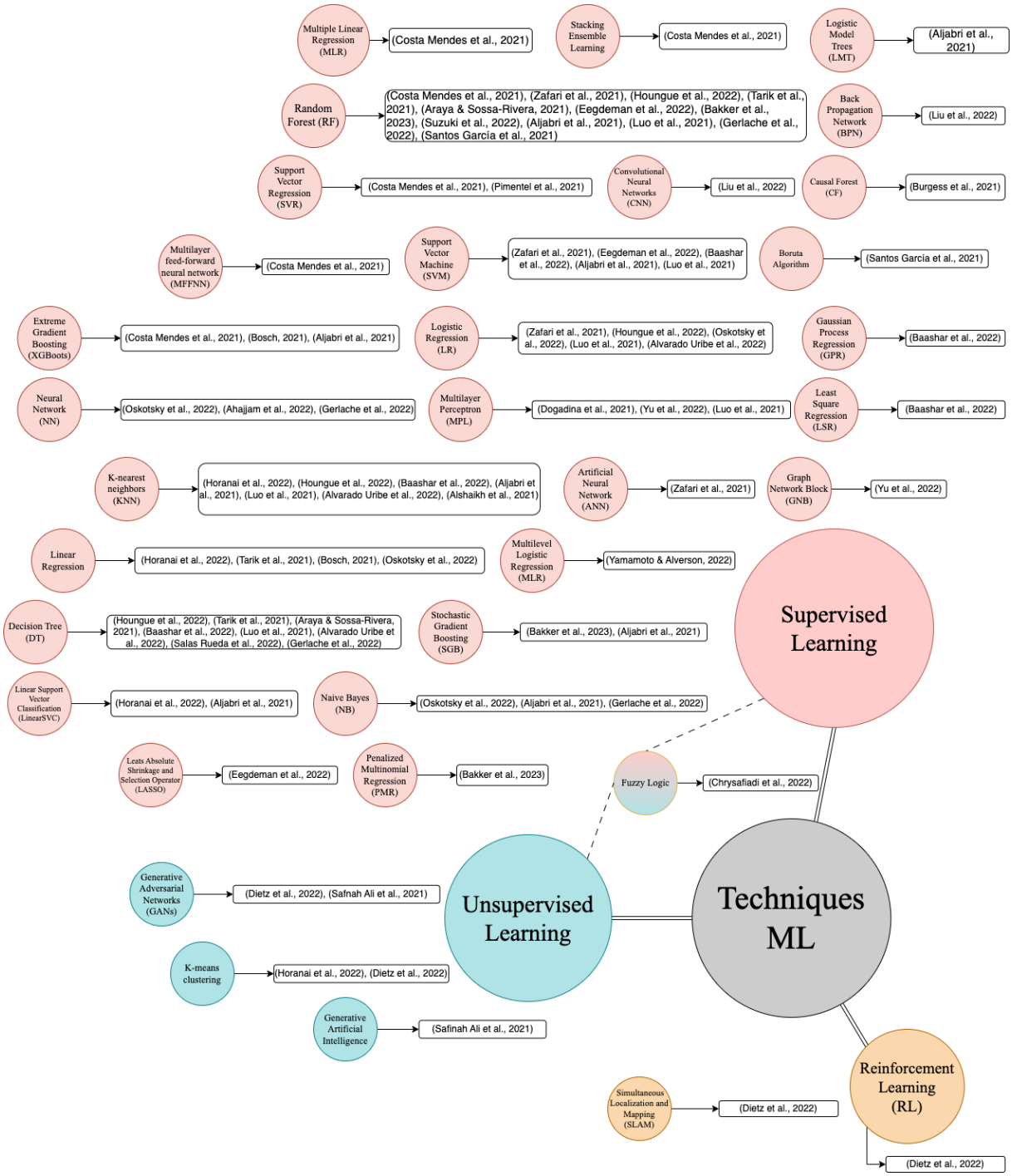
Figures 7 and 8 provide information in response to the fourth question.
ML techniques are classified according to the type of learning:

- **Supervised learning:** Learning from labelled data (Segura et al., 2022).
- **Unsupervised learning:** Learning from unlabelled data (Taha et al., 2018).
- **Semi-supervised learning:** Learning from labelled and unlabelled data (Chrysafiadi et al., 2022).
- **Reinforcement learning:** Learning from interactions with their environment (Dietz et al., 2022).

Figure 8 classifies the techniques according to the type of learning: supervised, unsupervised and reinforcement learning. The names of the techniques in English and their initials are maintained in relation to other scientific papers.

Figure 8

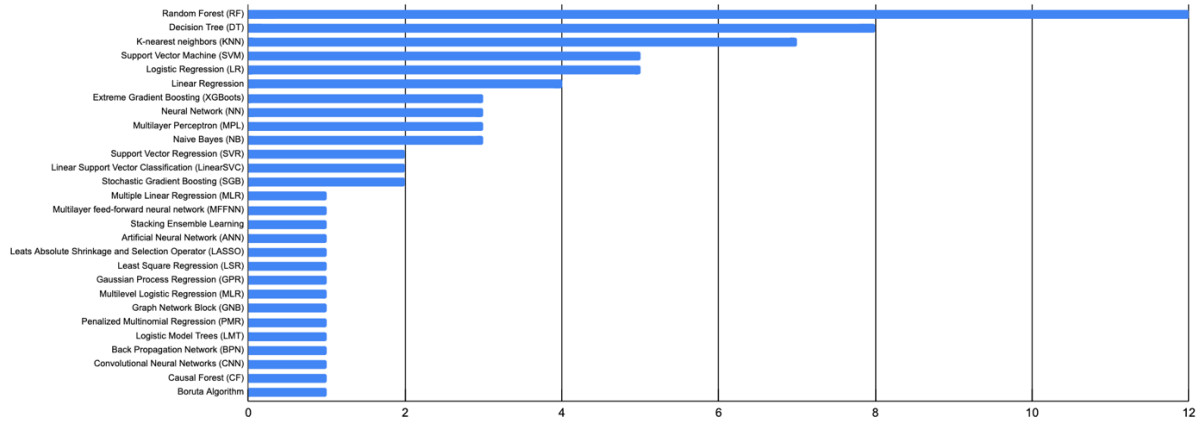
ML techniques found in ML studies (Supervised learning, Unsupervised learning, Semi-supervised learning, Reinforcement learning)



Source: own elaboration.

Figure 9 represents the frequency of supervised learning techniques found in the studies. The most commonly used techniques in the studies are as follows *Random Forest* (RF), *Decision Tree* (DT) *and K-nearest neighbors* (KNN), being the least used *Boruta Algoritm, Causal Forest* (CF), *Convolution Neural Networks* (CNN), *Back Propagation Network* (BPN), *Logistic Model Trees* (LMT), *Penalized Multinomial Regression* (PMR), *Graph Network Block* (GNB), *Multilayer Logistic regression* (MLR), *Gaussian Process Regression* (GPR), *Least Square Regression* (LSR), *Leasts Absolute Shrinkage and Selection Operator* (LASSO), *Artificial Neural Network* (ANN), *Stacking Emsemble Learning, Multilayer feed-fodward neural network* (MFFNN), *and Multilayer Linear Regression* (MLR).

Figure 9
Supervised learning techniques in studies



Source: own elaboration.

RQ5: What were the results of implementing ML or AI as an emerging technology in education?

In response to the fifth research question, Table 5 can be found in the main section of the **Annex**. This table presents the research study, the sample, methodology and results. The order is established according to the order criteria in Table 3.

According to the results in Table 5, the opportunities for improvement in teaching-learning processes and educational management can be grouped into the following categories: prediction of academic performance and school dropout, analysis of student and teacher perception, development of virtual robotics, learning on generative models, implementation of AI and ML, insertion of computational thinking at all levels, strengthening the legal framework in education, efficiency of school management, social robotics intervention, computer security training, incorporation of AI in clinical education, STEM for forensic analysis and AI support in students with special educational needs (SEN), among others. These enhancement opportunities can help improve student academic performance, reduce dropout rates, strengthen educational equity, and improve the overall quality of education.

The studies highlight predictions at the institutional level; however, classroom-level predictions are also recommended because they are more accurate and are based on more specific data on individual students. Nevertheless, institution-level

predictions can provide a more general view of academic performance since they are based on institution-wide data, such as grade point averages, attendance rates, graduation rates, dropout rates, etc.

The methodologies used in the studies were defined at two levels: research and teaching.At the research level, the aim was to find new knowledge and test hypotheses using quantitative,qualitative, or mixed methods. At the teaching level, the aim is to strengthen the TDC necessaryfor personal and professional development for student learning.

DISCUSSION AND CONCLUSIONS

This systematic literature review analyzed 55 references on the use of ML and AI in education conducted in 38 countries, with the United States leading the way, from primary school through university levels. The results show that the 33 intelligent techniques extracted from the studies can be applied in the education sector to:

- Detect students' academic performance early.
- Improve the educational skills of teachers.
- Facilitate the learning of students with autism spectrum disorders (ASD).
- Predict school dropout and make decisions about it.
- Improve and generate educational content.
- Close educational gaps.
- Implement AI teaching at all educational levels.
- Strengthen the information security of the educational community.
- Motivate learning through mobile devices.
- Strengthen the field of robotics.
- Improve academic and career guidance for students.
- Prevent the spread of fake news on social networks.
- Understand and reflect on the relationship between humans and machines.
- Develop critical thinking based on computational thinking.

The distribution of studies on the application of intelligent techniques in education is analyzed. The studies analyzed focused on the use of AI and ML techniques. The results show that the application of intelligent techniques in education is gaining ground at all educational levels. In the past, most of this research focused on the university sector (Forero & Negre Bennasar, 2022), but 74.6% of the analyzed studies were applied at the primary school and secondary school level. Our review is more comprehensive than other systematic reviews, as it analyzes studies at all primary, secondary and university levels.

Table 3 shows that 20% of the selected studies addressed COVID-19 in some way. This significant increase compared to other systematic reviews is since the studies were conducted between 2021 and February 2023, when much of this research was still ongoing during the pandemic. The COVID-19 pandemic has been a major global event that has had a significant impact on all aspects of life. Consequently, it is not surprising that many scientific studies have focused their attention on this issue. From our review it can be inferred that one in five studies focused on the COVID-19 disease and its consequences.

In recent years, there has been an increase in the publication of research from non-English-speaking countries in high-impact English-language scientific journals. This is due to the growing importance of science and technology in the globalized world, increased investment in research and development in emerging countries, and the need to share knowledge and results with a wider scope. In Latin America, Brazil, Mexico, Chile, and Ecuador are the countries that have experienced the greatest growth because they have a strongscience and technology base and are increasingly investing in research. In Europe, Spain, the Netherlands, Portugal, Italy, Greece, Switzerland, Lithuania, Finland, Slovenia, Russia, and Turkey are some of the countries leading the growth as they have a long scientific tradition and are committed to international research. In Africa, Benin, Cape Verde, Angola, Morocco, Nigeria, Ghana, Tanzania, Kenya, South Africa, and Namibia have experienced significant growth because they are increasingly investing in research to address the development challenges they face. In Asia, Japan, China, Saudi Arabia, Iran, Vietnam, South Korea, Qatar,India, Israel, and Malaysia are always stepping up as they have strong economies and are increasingly investing in research to drive economic growth. This increase is a positive trend that is contributing to the globalization of science.

Figure 5 shows that California, Massachusetts, and Texas are the states with the highestconcentration of ML and AI research in education. This is because institutions such as the University of Southern California, the Massachusetts Institute of Technology and the University of North Texas are putting a lot of effort into this field. The authors of this researchare mainly engineers, which highlights the need to involve education professionals in the research process.

As can be seen in Figure 8, this study found 33 different ML techniques, which are classified into the four main categories of learning: supervised (28), semi-supervised (1), unsupervised (3) and reinforcement learning (1), some techniques are subgroups of others, such as Artificial Neural Network ANN (Zafari et al., 2021) and Neural Network NN (Oskotsky et al., 2022), but are not grouped together as a single technique, to respect the full name that appears in the research. This indicates that experts are increasingly convinced that ML techniques are appropriate and very important for educational research as they are recognizing the potential to improve educational understanding and practice through new models and methods of teaching-learning.

In line with the above, institutions can use smart techniques and tools to help their students. Grade prediction is a high-impact tool that can considerably benefit both students andinstitutions (Gerlache et al., 2022), for example, they can provide students with insight into theircurrent performance and potential for success, helping students to identify areas or subjects in which they need to improve and to take steps to improve their results. In addition, grade predictors can help students make decisions about their future careers, knowing how they will do in a particular career, students can make more robust decisions about what to study andwhere they want to work in the future.

The most frequent applications using ML techniques focus on the prediction of academic performance, in particular, the *Random Forest* algorithm is the most frequently usedin these investigations, which is a supervised learning technique with high prediction probability. An example of the effectiveness of *Random Forest* for academic performance prediction is a study by Houngue et al. (2022) where it achieved 99% prediction accuracy. However, where there are other techniques with good probability, the choice will depend on the type of data available and the specific objective of the study. In general, ML algorithms have achieved a higher predictive level compared to classical models (Costa Mendes et al., 2021), this is because ML

algorithms can learn complex patterns in the data, which allows them to generate more accurate predictions.

The research sample handles a large amount of information, since, for ML techniques to be effective in their predictive capacity, it is necessary for the data to be correctly labelled. Therefore, Big Data comes to play an important role, where the role of the data must maintain those aspects of ethical and moral integrity regarding the information of both the participants (Blease et al., 2021) as well as the curriculum (Eguchi et al., 2021). Both studies agree that thedata used for ML must be ethical and moral, as biases in the data can negatively affect the accuracy of the models.

ML studies are developing new techniques that can improve the prediction system in the education sector. For example, the study by Suzuki et al. (2022) used an ML model to predict the academic performance of primary school students in Japan with an error of 10%. The study by Tarik et al. (2021) used an ML model to predict class attendance of university students in Malaysia with an error of 5%. Thus, being able to effectively predict educational management by minimizing errors at the technical level and at the institutional level enables problem solving in dynamic educational contexts.

The TDC is indispensable for teachers, as it assesses their skills in the knowledge and use of digital technologies. Therefore, identifying these opportunities for improvement in teaching-learning processes helps to mainstream ML and AI concepts in all subject areas and levels of knowledge. The teachers from different subject areas and with different levels of computer science training may have different conceptions of how to integrate ML concepts in schools (Temitayo et al., 2022). Therefore, this paper also seeks to raise awareness about the importance of teachers, regardless of their background, having the necessary skills and competences to apply ML and AI in the classroom. The integration of smart technologies is a crucial educational innovation across all subject areas and educational levels, as it has the potential to bridge the digital and school divide that has become a challenge for education experts.

LIMITATIONS AND FUTURE WORK

This review, due to its current subject matter, broad scope and to limit the proposed methodology, only studies in English have been analyzed. However, it is possible that there is research in ML and AI applied to education in other languages that have not been considered and that could be of interest.

Although the WoS and Scopus databases have been used to narrow down the study, the research could be extended by consulting other databases, as they could yield interesting resultson ML and AI.

It is necessary to strengthen education systems in Latin America, Africa, and Oceania with the implementation of AI and ML experiences and research, improving the provision of human and physical resources and quality teacher training, especially in the TDC.

The equation used allows the implicit integration of certain studies with the keyword “K-12” (Ali, DiPaola, Lee, Sindato et al., 2021; An et al., 2022; Duncan et al., 2022; Eguchi et al., 2021; Sanusi et al., 2022). However, it does not include references to the keywords “high* education*”, “ungraduate*”, “vocational training*”, “vocational education”, “adult education” or “corporate training*”. This could be of interest for future work, as these keywords could broaden the scope of the research.

The curricula of subjects must incorporate the concepts of new intelligent technologiesin a cross-cutting manner. To this end, it is necessary for educational and

institutional management to strengthen the competences of teachers and students in these new educational fields.

Despite the scarcity of research related to diversity, learners with special educational needs, disability and illness, there is a need to deepen and strengthen these fields to close gaps and have a positive impact on education and society.

Finally, it is hoped that this research will contribute to the knowledge and understanding of educational practices with ML and AI and how these can be implemented to strengthen teaching-learning and educational management processes in all types of contexts.

REFERENCES

Ahajjam, T., Moutaib, M., Aissa, H., Azrour, M., Farhaoui, Y., & Fattah, M. (2022). Predicting Students' Final Performance Using Artificial Neural Networks. *Big Data Mining and Analytics*, *5*(4), 294-301. https://doi.org/10.26599/BDMA.2021.9020030

Ahmed, A., Aziz, S., Qidwai, U., Farooq, F., Shan, J., Subramanian, M., Chouchane, L., EINatour, R., Abd-Alrazaq, A., Pandas, S., & Sheikh, J. (2023). Wearable Artificial Intelligence for Assessing Physical Activity in High School Children. *Sustainability (Switzerland)*, *15*(1), 1-12. https://doi.org/10.3390/su15010638

Ali, S., DiPaola, D., Lee, I., Sindato, V., Kim, G., Blumofe, R., & Breazeal, C. (2021). Children as creators, thinkers and citizens in an AI-driven future. *Computers and Education: Artificial Intelligence*, *2*, 100040. https://doi.org/10.1016/j.caeai.2021.100040

Ali, S., DiPaola, D., Lee, I., Hong, J., & Breazeal, C. (2021). Exploring generative models with middle school students. *Conference on Human Factors in Computing Systems - Proceedings*. https://doi.org/10.1145/3411764.3445226

Aljabri, M., Chrouf, S. M. B., Alzahrani, N. A., Alghamdi, L., Alfehaid, R., Alqarawi, R., Alhuthayfi, J., & Alduhailan, N. (2021). Sentiment analysis of arabic tweets regarding distance learning in saudi arabia during the covid-19 pandemic. *Sensors*, *21*(16). https://doi.org/10.3390/s21165431

Almeida Pereira Abar, C. A., Dos Santos Dos Santos, J. M., & de Almeida, M. V. (2021). Computational Thinking in Elementary School in the Age of Artificial Intelligence: Where is the Teacher? *Revista de Ensino de Ciencias y Matemática*, *23*(6), 270-299. https://doi.org/10.17648/acta.scientiae.6869

Almoqbil, A., O'Connor, B. C., Anderson, R., Shittu, J., & McLeod, P. (2021). Modeling deception: A case study of email phishing. *Proceedings from the Document Academy*, *8*(2). https://doi.org/10.35492/docam/8/2/8

Alshaikh, K., Bahurmuz, N., Torabah, O., Alzahrani, S., Alshingiti, Z., & Meccawy, M. (2021). Using Recommender Systems for Matching Students with Suitable Specialization: An Exploratory Study at King Abdulaziz University. *International Journal of Emerging Technologies in Learning*, *16*(3), 316-324. https://doi.org/10.3991/ijet.v16i03.17829

Alvarado Uribe, J., Mejía Almada, P., Masetto Herrera, A. L., Molontay, R., Hilliger, I., Hegde, V., Montemayor Gallegos, J. E., Ramírez Díaz, R. A., & Ceballos, H. G. (2022). Student Dataset from Tecnologico de Monterrey in Mexico to Predict Dropout in Higher Education. *Data*, *7*(9). https://doi.org/10.3390/data7090119

An, X., Chai, C. S., Li, Y., Zhou, Y., Shen, X., Zheng, C., & Chen, M. (2022). Modeling English teachers' behavioral intention to use artificial intelligence in middle schools. *Education and Information Technologies*. https://doi.org/10.1007/s10639-022-11286-z

Angara, P. P., Stege, U., MacLean, A., Muller, H. A., & Markham, T. (2022). Teaching Quantum Computing to High-School-Aged Youth: A Hands-On Approach. *IEEE Transactions on Quantum Engineering*, *3*. https://doi.org/10.1109/TQE.2021.3127503

Araya, R., & Sossa-Rivera, J. (2021). Automatic Detection of Gaze and Body Orientation in Elementary School Classrooms. *Frontiers in Robotics and AI*, *8*(September), 1-11. https://doi.org/10.3389/frobt.2021.729832

Ayanwale, M. A., Sanusi, I. T., Adelana, O. P., Aruleba, K. D., & Oyelere, S. S. (2022). Teachers' readiness and intention to teach artificial intelligence in schools. *Computers and Education: Artificial Intelligence*, *3*(August), 100099. https://doi.org/10.1016/j.caeai.2022.100099

Baashar, Y., Hamed, Y., Alkawsi, G., Fernando

Capretz, L., Alhussian, H., Alwadain, A., & Al-amri, R. (2022). Evaluation of postgraduate academic performance using artificial intelligence models. *Alexandria Engineering Journal*, *61*(12), 9867-9878. https://doi.org/10.1016/j.aej.2022.03.021

Bakker, T., Krabbendam, L., Bhulai, S., Meeter, M., & Begeer, S. (2023). Predicting academic success of autistic students in higher education. *Autism*. https://doi.org/10.1177/13623613221146439

Ban, H., & Ning, J. (2021). Online English Teaching Based on Artificial Intelligence Internet Technology Embedded System. *Mobile Information Systems*, *2021*. https://doi.org/10.1155/2021/2593656

Bellas, F., Guerreiro-Santalla, S., Naya, M., & Duro, R. J. (2022). AI Curriculum for European High Schools: An Embedded Intelligence Approach. *International Journal of Artificial Intelligence in Education*, *0123456789*. https://doi.org/10.1007/s40593-022-00315-0

Bhavana, S., & Vijayalakshmi, V. (2022). AI-Based Metaverse Technologies Advancement Impact on Higher Education Learners. *WSEAS Transactions on Systems*, *21*, 178-184. https://doi.org/10.37394/23202.2022.21.19

Blease, C., Kharko, A., Annoni, M., Gaab, J., & Locher, C. (2021). Machine Learning in Clinical Psychology and Psychotherapy Education: A Mixed Methods Pilot Survey of Postgraduate Students at a Swiss University. *Frontiers in Public Health*, *9*(April). https://doi.org/10.3389/fpubh.2021.623088

Bogina, V., Hartman, A., Kuflik, T., & Shulner-Tal, A. (2022). Educating Software and AI Stakeholders About Algorithmic Fairness, Accountability, Transparency and Ethics. *International Journal of Artificial Intelligence in Education*, *32*(3), 808-833. https://doi.org/10.1007/s40593-021-00248-0

Bosch, N. (2021). Identifying supportive student factors for mindset interventions: A two-model machine learning approach. *Computers and Education*, *167*(March), 104190. https://doi.org/10.1016/j.compedu.2021.104190

Bruno, G. di D. (2021). Erwhi Hedgehog: A New Learning Platform for Mobile Robotics. In *Lecture Notes in Networks and Systems* (Vol. 240). Springer International Publishing. https://doi.org/10.1007/978-3-030-77040-2_32

Burgess, S., Metcalfe, R., & Sadoff, S. (2021). Understanding the response to financial and non-financial incentives in education: Field experimental evidence using high-stakes assessments. *Economics of Education Review*, *85*(July), 102195. https://doi.org/10.1016/j.econedurev.2021.102195

Byun, A., & Kim, H. (2022). The Effect of Design Classes Using Artificial Intelligence in the Era of COVID-19 on Social Responsibility of High School Students. *Archives of Design Research*, *35*(4), 251-266. https://doi.org/10.15187/adr.2022.11.35.4.251

Ceha, J., Law, E., Kulić, D., Oudeyer, P. Y., & Roy, D. (2022). Identifying Functions and Behaviours of Social Robots for In-Class Learning Activities: Teachers' Perspective. *International Journal of Social Robotics*, *14*(3), 747-761. https://doi.org/10.1007/s12369-021-00820-7

Chen, B., Chen, H., & Li, M. (2021). Improvement and Optimization of Feature Selection Algorithm in Swarm Intelligence Algorithm Based on Complexity. *Complexity*, *2021*. https://doi.org/10.1155/2021/9985185

Cheng, J., Chae, M. H. C., & Feng, R. (2021). Stem education-career pathway for emerging forensic analytics: Innovative professional development in multimodal environments. *Journal of Higher Education Theory and Practice*, *21*(8), 115-130. https://doi.org/10.33423/jhetp.v21i8.4509

Chrysafiadi, K., Virvou, M., Tsihrintzis, G. A., & Hatzilygeroudis, I. (2022). Evaluating the user's experience, adaptivity and learning outcomes of a fuzzy-based intelligent tutoring system for computer programming for academic students in Greece. In *Education and Information Technologies* (Issue 0123456789). Springer US. https://doi.org/10.1007/s10639-022-11444-3

Costa Mendes, R., Oliveira, T., Castelli, M., & Cruz Jesus, F. (2021). A machine learning approximation of the 2015 Portuguese high school student grades: A hybrid approach. *Education and Information Technologies*, *26*(2), 1527-1547. https://doi.org/10.1007/s10639-020-10316-y

Dai, Y., Liu, A., Qin, J., Guo, Y., Jong, M. S. Y., Chai, C. S., & Lin, Z. (2022). Collaborative construction of artificial intelligence curriculum in primary schools. *Journal of Engineering Education*, *October 2022*, 23-42. https://doi.org/10.1002/jee.20503

Demchenko, M. V., Gulieva, M. E., Larina, T. V., & Simaeva, E. P. (2021). Digital Transformation of Legal Education: Problems, Risks and Prospects. *European Journal of Contemporary Education*, *10*(2), 297-307. https://doi.org/10.13187/ejced.2021.2.297

Demir, K., & Güraksın, G. E. (2022). Determining middle school students' perceptions of the concept of artificial intelligence: A metaphor analysis. *Participatory Educational Research*, *9*(2), 297-312. https://doi.org/10.17275/per.22.41.9.2

Dietz, G., Chen, J. K., Beason, J., Tarrow, M., Hilliard, A., & Shapiro, R. B. (2022). ARtonomous: Introducing Middle School Students to Reinforcement Learning Through Virtual Robotics. *Proceedings of Interaction Design and Children, IDC 2022*, 430-441. https://doi.org/10.1145/3501712.3529736

Dogadina, E. P., Smirnov, M. V., Osipov, A. V., & Suvorov, S. V. (2021). Formation of the optimal load of high school students using a genetic algorithm and a neural network. *Applied Sciences (Switzerland)*, *11*(11). https://doi.org/10.3390/app11115263

Duncan, D., Garner, R., Bennett, A., Sinclair, M., Ramirez-De La Cruz, G., & Pasik-Duncan, B. (2022). Interdisciplinary K-12 Control Education in Biomedical and Public Health Applications. *IFAC-PapersOnLine*, *55*(17), 242-248. https://doi.org/10.1016/j.ifacol.2022.09.286

Duzhin, F., & Gustafsson, A. (2018). Machine learning-based app for self-evaluation of teacher-specific instructional style and tools. *Education Sciences*, *8*(1), 1-15. https://doi.org/10.3390/educsci8010007

Eegdeman, I., Cornelisz, I., van Klaveren, C., & Meeter, M. (2022). Computer or teacher: Who predicts dropout best? *Frontiers in Education*, *7*(November), 1-10. https://doi.org/10.3389/feduc.2022.976922

Eguchi, A., Okada, H., & Muto, Y. (2021). Contextualizing AI Education for K-12 Students to Enhance Their Learning of AI Literacy Through Culturally Responsive Approaches. *KI - Kunstliche Intelligenz*, *35*(2), 153-161. https://doi.org/10.1007/s13218-021-00737-3

Fernández-Martínez, C., Hernán-Losada, I., & Fernández, A. (2021). Early Introduction of AI in Spanish Middle Schools. A Motivational Study. *KI - Kunstliche Intelligenz*, *35*(2), 163-170. https://doi.org/10.1007/s13218-021-00735-5

Forero Corba, W., & Negre Bennasar, F. (2022). Revisión sistemática de la aplicación del Machine Learning en la Educación. *EDUTEC Educación transformadora en un mundo digital: Conectando paisajes de aprendizaje*, 416-419. http://dspace.uib.es/xmlui/handle/11201/160593

Gerlache, H. A. M., Ger, P. M., & Valentín, L. de la F. (2022). Towards the Grade's Prediction. A Study of Different Machine Learning Approaches to Predict Grades from Student Interaction Data. *International Journal of Interactive Multimedia and Artificial Intelligence*, *7*(4), 196-204. https://doi.org/10.9781/ijimai.2021.11.007

Giam, N. M., Nam, N. T. H., & Giang, N. T. H. (2022). Situation and Proposals for Implementing Artificial Intelligence-based Instructional Technology in Vietnamese Secondary Schools. *International Journal of Emerging Technologies in Learning*, *17*(18), 53-75. https://doi.org/10.3991/ijet.v17i18.31503

Horanai, H., Maejima, Y., & Ding, L. (2022). An Education Tool at Supports Junior Learners in Studying Machine Learning. *Frontiers in Artificial Intelligence and Applications*, *360*, 111-116. https://doi.org/10.3233/FAIA220432

Houngue, P., Hountondji, M., & Dagba, T. (2022). An Effective Decision-Making Support for Student Academic Path Selection using Machine Learning. *International Journal of Advanced Computer Science and Applications*, *13*(11), 727-734. https://doi.org/10.14569/IJACSA.2022.0131184

Liu, Y., Chen, L., & Yao, Z. (2022). The application of artificial intelligence assistant to deep learning in teachers' teaching and students' learning processes. *Frontiers in Psychology*, *13*. https://doi.org/10.3389/fpsyg.2022.929175

Luan, H., & Tsai, C. C. (2021). A Review of Using Machine Learning Approaches for Precision Education. *Educational Technology and Society*, *24*(1), 250–266.

Luo, F., Jiang, L., Tian, X., Xiao, M., Ma, Y., & Zhang, S. (2021). Shyness prediction and language style model construction of elementary school students. *Acta Psychologica Sinica*, *53*(2), 155-169. https://doi.org/10.3724/SP.J.1041.2021.00155

Marín, V. I. (2022). The systematic review in Educational Technology research: observations and advice. *RiiTE Revista Interuniversitaria de Investigación En*

Tecnología Educativa, *13*, 62-79. https://doi.org/10.6018/riite.533231

Mittal, S., Mahendra, S., Sanap, V., & Churi, P. (2022). International Journal of Information Management Data Insights How can machine learning be used in stress management : A systematic literature review of applications in workplaces and education. *International Journal of Information Management Data Insights*, *2*(2), 100110. https://doi.org/10.1016/j.jjimei.2022.100110

Nafea, I. T. (2018). Machine Learning in Educational Technology. *Machine Learning - Advanced Techniques and Emerging Applications*. https://doi.org/10.5772/intechopen.72906

Oskotsky, T., Bajaj, R., Burchard, J., Cavazos, T., Chen, I., Connell, W., Eaneff, S., Grant, T., Kanungo, I., Lindquist, K., Myers-Turnbull, D., Naing, Z. Z. C., Tang, A., Vora, B., Wang, J., Karim, I., Swadling, C., Yang, J., Lindstaedt, B., & Sirota, M. (2022). Nurturing diversity and inclusion in AI in Biomedicine through a virtual summer program for high school students. *PLoS Computational Biology*, *18*(1), 1-12. https://doi.org/10.1371/journal.pcbi.1009719

Pimentel, J. S., Ospina, R., & Ara, A. (2021). Learning Time Acceleration in Support Vector Regression: A Case Study in Educational Data Mining. *Stats*, *4*(3), 682-700. https://doi.org/10.3390/stats4030041

Salas-Pilco, S. Z., & Yang, Y. (2022). Artificial intelligence applications in Latin American higher education: a systematic review. *International Journal of Educational Technology in Higher Education*, *19*(1). https://doi.org/10.1186/s41239-022-00326-w

Salas Rueda, R. A., De la cruz Martínez, G., Eslava Cervantes, A. L., Castañeda Martínez, R., & Ramírez Ortega, J. (2022). Teachers' opinion about collaborative virtual walls and massive open online course during the COVID-19 pandemic. *Online Journal of Communication and Media Technologies*, *12*(1), 1-13. https://doi.org/10.30935/ojcmt/11305

Santos García, F., Valdivieso, K. D., Rienow, A., & Gairín, J. (2021). Urban–Rural Gradients Predict Educational Gaps: Evidence from a Machine Learning Approach Involving Academic Performance and Impervious Surfaces in Ecuador. *ISPRS International Journal of Geo-Information*, *10*(12). https://doi.org/10.3390/ijgi10120830

Sanusi, I. T., Oyelere, S. S., & Omidiora, J. O. (2022). Exploring teachers' preconceptions of teaching machine learning in high school: A preliminary insight from Africa. *Computers and Education Open*, *3* (November 2021), 100072. https://doi.org/10.1016/j.caeo.2021.100072

Sasmita, F., & Mulyanti, B. (2020). Development of machine learning implementation in engineering education: A literature review. *IOP Conference Series: Materials Science and Engineering*, *830*(3). https://doi.org/10.1088/1757-899X/830/3/032061

Segura, M., Mello, J., & Herná, A. (2022). *Machine Learning Prediction of University Student Dropout: Does Preference Play a Key Role?* 1-20. https://doi.org/10.3390/math10183359

Su, J., Zhong, Y., Tsz, D., & Ng, K. (2022). Computers and Education : Artificial Intelligence A meta-review of literature on educational approaches for teaching AI at the K-12 levels in the Asia-Pacific region. *Computers and Education: Artificial Intelligence*, *3*(March), 100065. https://doi.org/10.1016/j.caeai.2022.100065

Suzuki, H., Hong, M., Ober, T., & Cheng, Y. (2022). Prediction of differential performance between advanced placement exam scores and class grades using machine learning. *Frontiers in Education*, *7*(December). https://doi.org/10.3389/feduc.2022.1007779

Taha, S. A., Shihab, R. A., & Sadik, M. C. (2018). Studying of Educational Data Mining Techniques. *International Journal of Advanced Research in Science, Engineering and Technology*, *5*(5), 5742-5750. http://www.ijarset.com/upload/2018/may/9-IJARSET-SAJATAHA.pdf

Tarik, A., Aissa, H., & Yousef, F. (2021). Artificial intelligence and machine learning to predict student performance during the COVID-19. *Procedia Computer Science*, *184*, 835-840. https://doi.org/10.1016/j.procs.2021.03.104

Temitayo, I., Sunday, S., & Olamide, J. (2022). Exploring teachers ' preconceptions of teaching machine learning in high school : A preliminary insight from Africa. *Computers and Education Open*, *3*(November 2021), 100072. https://doi.org/10.1016/j.caeo.2021.100072

Van Brummelen, J., Tabunshchyk, V., & Heng, T. (2021). "Alexa, Can I Program You?": Student Perceptions of Conversational Artificial Intelligence before and after Programming Alexa. *Proceedings of Interaction Design and Children, IDC 2021*, 305-313.

https://doi.org/10.1145/3459990.3460730

Yamamoto, S. H., & Alverson, C. Y. (2022). From high school to postsecondary education, training, and employment: Predicting outcomes for young adults with autism spectrum disorder. *Autism and Developmental Language Impairments*, *7*. https://doi.org/10.1177/23969415221095019

Yepes-Nuñez, J. J., Urrútia, G., Romero-García, M., & Alonso-Fernández, S. (2021). The PRISMA 2020 statement: an updated guideline for reporting systematic reviews. *Revista Espanola de Cardiologia*, *74*(9), 790-799. https://doi.org/10.1016/j.recesp.2021.06.016

Yu, Y., Fan, J., Xian, Y., & Wang, Z. (2022). Graph Neural Network for Senior High Student's Grade Prediction. *Applied Sciences (Switzerland)*, *12*(8). https://doi.org/10.3390/app12083881

Zafari, M., Sadeghi-Niaraki, A., Choi, S. M., & Esmaeily, A. (2021). A practical model for the evaluation of high school student performance based on machine learning. *Applied Sciences (Switzerland)*, *11*(23). https://doi.org/10.3390/app112311534

Zawacki-Richter, O., Kerres, M., Bedenlier, S., & Buntins, K. (2020). Systematic Reviews in Educational Research. In *Systematic Reviews in Educational Research*. https://doi.org/10.1007/978-3-658-27602-7

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education – where are the educators? *International Journal of Educational Technology in Higher Education*, *16*(1). https://doi.org/10.1186/s41239-019-0171-0

Zhai, X., Chu, X., Chai, C. S., Jong, M. S. Y., Istenic, A., Spector, M., Liu, J. B., Yuan, J., & Li, Y. (2021). A Review of Artificial Intelligence (AI) in Education from 2010 to 2020. *Complexity*, *2021*. https://doi.org/10.1155/2021/8812542

Zhu, J., & Liu, W. (2020). A tale of two databases: the use of Web of Science and Scopus in academic papers. *Scientometrics*, *123*(1), 321-335. https://doi.org/10.1007/s11192-020-03387-8

APPENDIX

Table 5
Characteristics of the reviewed studies

Nº	Study	Sample	Methodology	Results
1	(Araya & Sossa-Rivera, 2021)	4 teachers and first grade students	Basic heuristics	It is possible to estimate the direction of the teacher and the orientation of the head and body of students with ML.
2	(Dai et al., 2022)	23 primary school computer science teachers	Triangulation between ethnographic observation, interviews, and artefacts with teachers.	Influences for curricular incorporation of AI faculty at a partner university
3	(Almeida Pereira Abar et al., 2021)	11 teachers	Qualitative and action-research	Computational thinking in basic education helps children in solving all kinds of problems.
4	(Ceha et al., 2022)	5 primary school and secondary school teachers	Participatory design, qualitative method, Engeström's Activity System Model	The teachers answered positively to the idea of introducing a social robot as a technological tool for learning activities.
5	(Luo et al., 2021)	1,306 primary school students on an online learning platform	Application of ML algorithms	Students with shy behavior, cognitive and emotional problems have unique characteristics in language style.
6	(Costa Mendes et al., 2021)	362,261 scores of pre-schools, primary and secondary school student	Mixed (Quantitative and Qualitative)	Socio-economic indices have inherently limited predictive power.
7	(Aljabri et al., 2021)	3,200 tweets in Arabic	Analysis of people's tweets about distance learning in Saudi Arabia	This result can be used by the Ministry of Education to further improve the distance learning education system.
8	(Van Brummelen et al., 2021)	47 students	Student perception workshops	The students felt that Alexa was very intelligent and they felt closer to her.
9	(Zafari et al., 2021)	246 secondary school students in open-ended physics questions.	Correlation Coefficient for Feature Selection and Application of ML Algorithms	ML models are influential in assessing students and improving the educational factor.
10	(Bellas et al., 2022)	30 students from 6 schools	Proactive learning (Learning by doing)	Fully practical curriculum based on the concept of the intelligent agent.

Nº	Study	Sample	Methodology	Results
11	(Horanai et al., 2022)	An educational tool with AI	Software development with ML	Students have a better understanding of the fundamentals of AI and ML, increasing their interest in the future development of AI applications.
12	(Houngue et al., 2022)	325 grades grade 6 to grade 9	Application of ML algorithms	The performance of five ML algorithms in predicting students' scientific or literary ability was compared.
13	(Tarik et al., 2021)	72,010 students between 2,000 and 2015	Application of ML algorithms	The best model for predicting high school Grade Point Average GPA using an RF regression algorithm.
14	(Dietz et al., 2022)	15 students with learning difficulties or low resources between 11-14 years old	Mixed Research (qualitative and quantitative)	Educational robotics tools, training and programming of simulated robots is attractive and educational for the participants.
15	(Ali, DiPaola, Lee, Sindato et al., 2021)	38 secondary school students aged 10 to 15 years, 18 females and 20 males	5-day virtual workshop to teach about generative ML.	Students demonstrated an understanding that deep-fakes can contribute to the spread of misinformation.
16	(Eegdeman et al., 2022)	9 teachers and 95 students	Teacher survey and use of ML algorithms	ML could help advance the use of evidence to make decisions and predictions in the education sector.
17	(Eguchi et al., 2021)	Teachers and curricula	K-12 student learning experiences.	70% of teachers felt insecure about implementing AI in their classrooms.
18	(Demir & Güraksın, 2022)	339 seventh and eighth grade students from 4 middle schools	Qualitative method analyzing metaphors	Most participants associated IA with humans, technology, and the brain.
19	(Fernández-Martínez et al., 2021)	84 students	Application of didactic unit with IA	It is necessary to rethink the planning for the introduction of AI in the curriculum.
20	(Ali, DiPaola, Lee, Hong y Breazeal, 2021)	72 students (grades 5-9)	Four online workshops	We found that the workshops enabled the children to understand what generative models are.
21	(Temitayo et al., 2022)	12 secondary school computer science teachers	Semi-structured interview	The need to train teachers to use introduce ML in their classes.
22	(Dogadina et al., 2021)	Course contents and 250 assignments	Pareto set and Application of ML algorithms	Minimizes student effort while maximizing the effectiveness of the educational process.
23	(Yamamoto & Alverson, 2022)	393 in 2017 and 387 in 2018 students with ASD	Two methods of predictive analytics (PA): Multilevel logistic regression and ML	The ML model with the best MLR performance in PSO prediction.

Nº	Study	Sample	Methodology	Results
24	(Yu et al., 2022)	Grades de 100 students	Application of ML algorithms	The proposed method works well in predicting the grades of high school students.
25	(Bosch, 2021)	16,310 students from 76 schools in grade 9	Implementation of 2 ML models	The intervention was most effective for students with low academic achievement.
26	(Chen et al., 2021)	68 students	Six classes at school No. 1 in the city	Students and teachers are very satisfied with the algorithm-based teaching
27	(Duncan et al., 2022)	3000 participants	Conferences and Workshops (Webinars)	Students from the beginning of their education should have knowledge and skills in ML and AI related topics.
28	(Pimentel et al., 2021)	5,095,270 students	Massive data set analysis	Using seven input variables, it is possible to accurately predict a student's average grade.
29	(An et al., 2022)	470 English teachers	Survey	Provide educators with policies to encourage AI teaching.
30	(Oskotsky et al., 2022)	18 in 2019, 29 in 2020, 27 in 2021 students admitted to the program UCSF AI4ALL	Evaluation of student transcripts, letters of recommendation and short essay responses.	More students were familiar with working with data and evaluating and applying ML algorithms.
31	(Ahajjam et al., 2022)	72,010 students enrolled between 2,000 and 2,015	Rating prediction using ML and data mining techniques.	The best results for good academic and career guidance were with the neural network algorithm which provided good scores and predictions.
32	(Suzuki et al., 2022)	381 students from 6 secondary schools	Application of ML algorithms	Early detection and intervention allow for the improvement of students' academic performance.
33	(Giam et al., 2022)	119 teachers from middle schools belonging to some cities in Vietnam	Likert-type survey, Quantitative analysis	Secondary teachers are aware of the need for AI implementation in secondary education.
34	(Cheng et al., 2021)	30 teachers	Integrated Model for Convergent Careers, Mixed Method	STEM CareerBuilder program had a positive impact on teachers and students.
35	(Ayanwale et al., 2022)	368 primary and secondary school teachers	Quantitative Structural Equation Modeling	Confidence and relevance in teaching AI predicts intention and readiness to teach AI in institutions.
36	(Angara et al., 2022)	Grade 9 - 12 students in Victoria and Broomfield	Unplugged activities designed to teach basic concepts of quantum computing.	Quantum computing, through its various avenues, is also accessible to people beyond high school.

Nº	Study	Sample	Methodology	Results
37	(Liu et al., 2022)	80 students	Comparative analysis of pre-test and post-tests, action research.	AI technology can act as a learning companion, indicating the problems faced by teachers during the teaching process.
38	(Byun & Kim, 2022)	96 secondary students	Art subject design based on trends, policies, and cases of AI education due to COVID-19.	Educational activities using AI had a positive impact on student participation and interest in class.
39	(Burgess et al., 2021)	10,649 students from 63 schools	Random selection of groups for financial incentives and non-financial incentives (travel).	Incentives in schools predicted to help close gaps.
40	(Santos García et al., 2021)	248,252 student records	Application of ML algorithms	High academic achievement was mainly related to responses related to academic environment and cognitive skills.
41	(Ahmed et al., 2023)	29 secondary school children (12 boys and 17 girls) from 13 to 17 years of age	Cross-sectional observational study to assess physical activity at various times of the day.	Need to design effective programs and strategies to improve physical activity in students.
42	(Bhavana & Vijayalakshmi, 2022)	597 secondary and higher education students	ARCS (attention, relevance, confidence, and satisfaction) model for analyzing Augmented Reality Education	The use and application of reality for smartphones would help students to learn and be more motivated.
43	(Bruno, 2021)	Robot Erwhi Hedgehog	Computer vision and ML	Accelerate and simplify the development of robotics for researchers, educators, students, and professionals.
44	(Demchenko et al., 2021)	129,666 students and 17,923 teachers in higher education	The chi-square test was used to test statistical hypotheses.	It is recommended to introduce tools to improve the digital skills of law students in the curricula.
45	(Bogina et al., 2022)	20 primary and secondary school teachers	Description and evaluation of some educational activities	Educational needs of professionals who produce algorithmic systems, should cover FATE aspects.
46	(Chrysafiadi et al., 2022)	140 undergraduate students	Quasi-experimental research	The intelligent tutor significantly improves student performance and achieves learning goals.
47	(Baashar et al., 2022)	635 master's degree students	Regression algorithms using MATLAB, model performance and predictive decision making.	Variables such as research, marital status and living conditions would have improved the accuracy of ML models.

Nº	Study	Sample	Methodology	Results
48	(Blease et al., 2021)	120 clinical psychology students in the master's program.	Mixed (Quantitative and Qualitative)	Formal education is limited on how AI/ML tools might affect psychotherapy.
49	(Almoqbil et al., 2021)	251,000 accounts of students, faculty, staff, alumni, and retirees, all over 18 years of age.	Information from phishing emails to the network administrator.	Phishing increased in the summer and vacation season, staff and students were the main target audience.
50	(Ban & Ning, 2021)	Primary school students	3 months of teaching in 6 classes.	The unique data of the educational system includes not only the conversation data generated by teacher-student interaction, but also educational management data.
51	(Bakker et al., 2023)	101 students with ASD at the Vrije Universiteit Amsterdam	Application of ML algorithms	Institutions can reduce the risk of dropout and increase school completion for autistic students.
52	(Alvarado Uribe et al., 2022)	121,584 secondary school and undergraduate students	Data life cycle	An appropriate model would benefit students with timely and personalized strategies to support their career retention.
53	(Salas Rueda et al., 2022)	54 teachers from the National Autonomous University of Mexico	Quantitative research	CVWs and MOOCs positively influence student learning and engagement.
54	(Gerlache et al., 2022)	4,522 records with data from master's degree students	Application of ML algorithms	AI can predict educational situations with an accuracy of over 96%.
55	(Alshaikh et al., 2021)	960 student registrations in science, medicine, computer science and engineering	Collaborative filtering technique was used to build the recommender system.	The specialization to be studied for each student was predicted with good accuracy.

Note: ASD: Autism Spectrum Disorder, RF: Random Forest, FATE: fairness, accountability, transparency, and ethics, MLR: multilevel logistic regression, PSO: post-high school outcomes, CVWs: Collaborative Virtual Walls (CVWs), MOOCs: Massive Open Online Courses.
Source: own elaboration.

Date of reception: 1 June 2023
Date of acceptance: 12 September 2023
Date of approval for layout: 10 October 2023
Date of publication in OnlineFirst: 27 October 2023
Date of publication: 1 January 2024