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Artificial intelligence and machine learning in education: A systematic review of applications, methods, and trends

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Abstract

Artificial intelligence (AI) and machine learning (ML) are increasingly influencing educational decision-making, learning support, and assessment. This paper presents a PRISMA-guided systematic literature review of AI and ML applications in education, with a specific analytical emphasis on ML-enabled educational applications. A literature search was conducted in Web of Science, Scopus, and Google Scholar for peer-reviewed English-language journal articles published between 2019 and 2025. The refined search strategy combined general AI/ML terms with application-specific keywords such as predictive analytics, learning analytics, personalized learning, intelligent tutoring systems, automated assessment, at-risk students, dropout prediction, and student attrition. Thirty-one studies met the inclusion criteria. Data were extracted and synthesized using content analysis and thematic analysis supported by a structured coding protocol. The findings show increased publication activity after 2021 and reveal five major application areas: predictive analytics, personalized learning, learning analytics, intelligent tutoring systems, and automated assessment. The review also identifies methodological limitations, including small samples, uneven geographic distribution, limited quality appraisal, and insufficient evidence from large-scale intervention studies. The paper contributes by clarifying the relationship between AI and ML in the review scope, strengthening the search strategy, mapping findings to the research questions, and identifying practical, theoretical, and ethical implications for educational institutions, policymakers, and educational technology developers.

Keywords: Artificial Intelligence, Machine Learning, Education, Learning Analytics, Predictive Analytics, Personalized Learning, Intelligent Tutoring Systems, Automated Assessment

Introduction

Artificial intelligence (AI) refers to computational systems that perform tasks normally associated with human intelligence, including reasoning, prediction, pattern recognition, recommendation, and language processing. Machine learning (ML) is a major subfield of AI that uses data-driven algorithms to detect patterns, make predictions, and improve performance through experience. In education, AI and ML have been applied to identify students at risk of failure, predict dropout or attrition, personalize learning pathways, analyze learning behavior, support intelligent tutoring, and automate assessment and feedback (Doleck et al., 2019; Shemshack & Spector, 2020; Lin et al., 2023). Because many education papers use

the terms AI and ML together, this review adopts an AI-and-ML scope while giving particular attention to applications in which ML techniques or ML-enabled analytics are central.

Prior reviews have examined specific areas such as predictive learning analytics, personalized learning, intelligent tutoring systems, and student performance prediction. However, these reviews are often concentrated on one application, one technology, or one educational level. The field therefore remains fragmented across different methodological traditions and application areas. A broader synthesis is needed to clarify how recent studies frame AI/ML in education, which methods dominate the literature, how major application areas are connected, and what gaps remain for future research. This positioning also addresses the need to distinguish between descriptive trend reporting and substantive thematic synthesis.

Accordingly, the study is guided by the following research questions:

Research questions:

RQ1: What publication, citation, and geographical trends can be identified in recent research on AI and machine learning applications in education from 2019 to 2025?

RQ2: What methodological patterns, study designs, sample characteristics, and analysis approaches are used in recent AI and machine learning research in education?

RQ3: What major application areas, antecedents, outcomes, theoretical foundations, and research gaps are reported in AI and machine learning studies in education?

Methodology

Review Design

In the present study, a PRISMA-guided systematic literature review was employed to investigate AI and machine learning applications in education. PRISMA was used as a reporting and transparency framework for identifying, screening, and reporting studies; it was not treated as a separate review methodology. The review followed a systematic process of identifying, collecting, evaluating, coding, and synthesizing relevant research literature to answer the research questions (Namoun & Alshanqiti, 2020). The design was selected because the field contains rapidly expanding but methodologically diverse work across predictive analytics, personalized learning, learning analytics, intelligent tutoring systems, and automated assessment.

Information Sources

The search was conducted on Web of Science and Scopus databases as these databases contain numerous education, computer science, and educational technology journals. The search utilized the title, abstract, and keyword fields for each database to find the most relevant scholarly articles. Finally, Google scholar was used as an additional database to search for articles regarding education and technology topics that may not have been as readily available on the other two databases.

Search Strategy

The search strategy was refined to reflect both AI and ML terminology as well as the areas of education in which the studies were applied. The resulting search string was as follows: ("machine learning" OR "artificial intelligence" OR "AI" OR "educational data mining") AND ("education" OR "higher education" OR "school" OR "student learning") AND ("predictive analytics" OR "learning analytics" OR "personalized learning" OR "adaptive learning" OR "intelligent tutoring systems" OR "automated assessment" OR "student performance prediction" OR "at-risk students" OR "student attrition" OR "dropout prediction") AND ("academic performance" OR "student achievement" OR "learning outcomes" OR "engagement" OR "feedback"). These terms were found through initial searches for relevant studies, citation of the keywords from other highly-cited research papers in the topic area, and through reviewing the keywords from other research reviews of these topics. The outcomes-specific keywords were utilized in particular because many

of the described research studies in education indicated the use of these outcome-based AI and machine learning methods and techniques.

Eligibility Criteria

All the studies that were included in this review met the pre-defined criteria for eligibility. To be eligible for inclusion in this review, the studies had to be published between the years of 2019 and 2025, must be published in a peer-reviewed journal, written in English, and discuss the use of artificial intelligence and machine learning in education. Studies that were published prior to 2019, published as conference papers, books, dissertations, and non-peer-reviewed publications, not written in English, and those that did not relate to education were excluded. Additionally, while the title of the studies did not include the words “machine learning” or “artificial intelligence,” those articles were still included in this review if their abstract, keywords, or the full-text publication indicated a discussion of artificial intelligence and machine learning in education. Table 1 presents these criteria for inclusion in this review.

Table 1. Inclusion and exclusion criteria

Sr. No	Inclusion Criteria	Exclusion Criteria
1.	Articles published between 2019 and 2025	Articles published before 2019
2.	Peer-reviewed journal articles	Conference papers, books, dissertations
3.	Articles published in English language	Non-English language
4.	Studies related to machine learning applications in education	Non-educational domains

Screening and Study Selection

A total of 2,350 records were identified through database searches. Through screening of the titles of the records, 382 records were identified as potentially relevant to the proposed study. Of these potentially relevant records, 38 were found to be duplicates through different database searches and were removed from the study. Through screening of abstracts of the remaining records, 246 records were excluded through not meeting the inclusion criteria for the study. The remaining records (n=98) were obtained for full-text screening. Of these full-text articles, 67 were excluded due to being out-of-scope with the study, lacking a focus on AI/ML education, providing no relevant applications of AI/ML to education, or not meeting publication-type requirements for the study. Thus, 31 articles were included in the review for analysis, as represented in Figure 1.

The screening process for articles followed the guidelines recommended in the PRISMA 2020 statement to increase the transparency of the study and to reduce any potential bias in the selection of these articles. More specifically, eligibility criteria for articles were established prior to the inception of the research and applied throughout the screening of articles for relevance. Furthermore, the screening process included two stages: screening of titles and abstracts to identify potentially relevant articles, and screening of the full-text articles to determine if they met the eligibility criteria (Page et al., 2021). Screening decisions were recorded in a decision log, with reasons for the exclusion of articles in the full-text screening stage. Any articles that were unclear if they would meet the eligibility criteria after the full-text screening were rechecked against the eligibility criteria. When screening decisions were unclear, the two reviewers independently rechecked the articles against the eligibility criteria, and cases that remained unclear were resolved through discussion between the two researchers to ensure that all decisions were reliable (Landis & Koch, 1977).

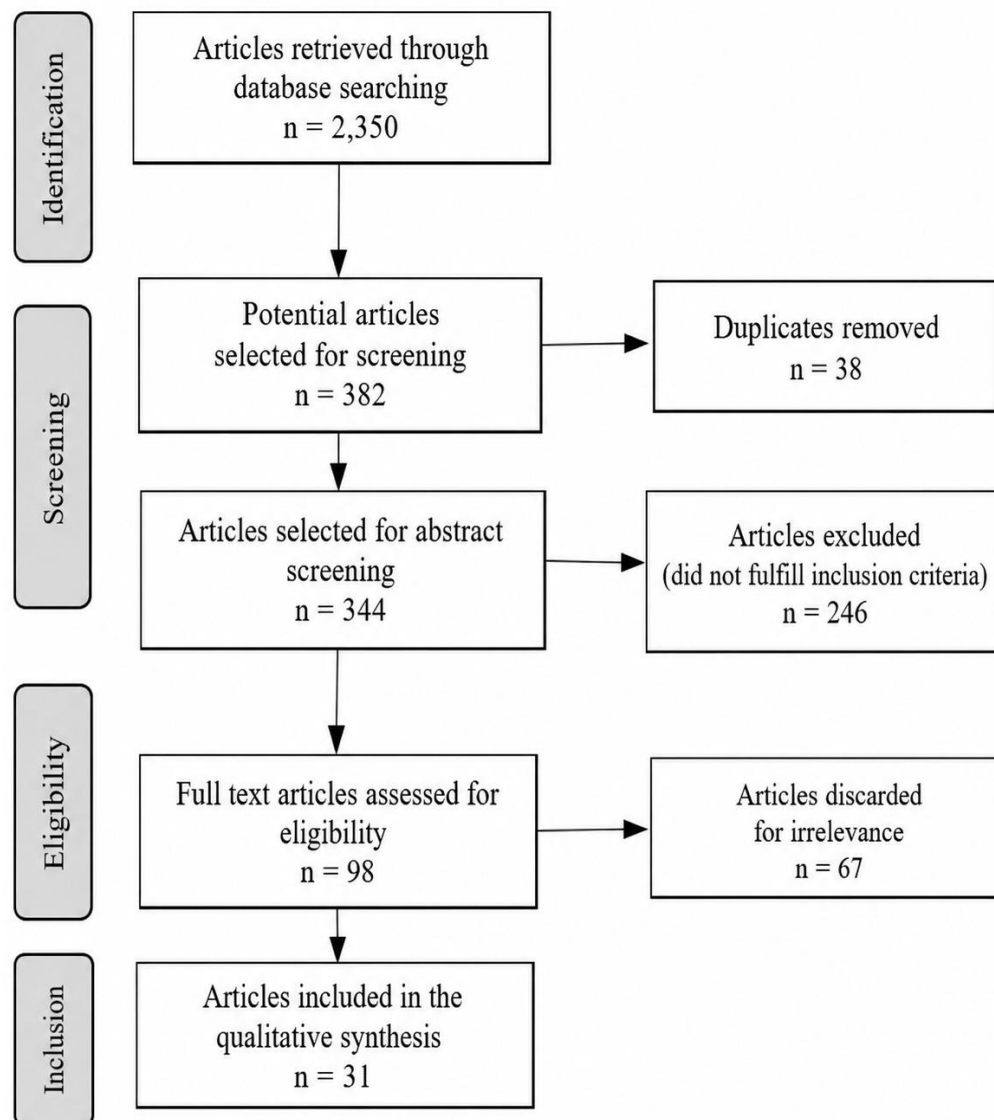


Figure 1. PRISMA flow diagram

Data Extraction and Synthesis

For each of the 31 studies, data was collected on the authors of the studies, the year of publication, the region in which they conducted their studies, the citations that their studies received, the objectives of each of the studies, the sample sizes within each of the studies, the types of research that they conducted, the designs of those studies, and the methods that they used to analyze their data. Each of the studies was coded during the performing of both a content analysis and a thematic analysis of the studies. The codes were applied to each of the studies during two separate rounds of coding - the first round of coding helped to describe each of the studies individually, and the second round of coding helped to group the studies according to the purposes for which they applied their AI or machine learning techniques. The codebook that was created for each of the studies was applied to each of the studies during both rounds of coding, additional reviews were performed for studies that were uncertain during the initial review, and additional codes were applied during a third round of coding to ensure that all studies were coded according to the codebook. The themes that emerged from each of the studies were determined through reviewing each of the studies and their findings, rather than being predetermined as a result of the search for such studies.

Finally, a brief appraisal of the quality of each of the studies was performed. Because the studies applied to this literature review employed different types of research and research designs, an appraisal of the quality of each study was performed according to indicators of the quality of research studies in general.

Results

RQ1: Publication, Citation, and Geographical Trends in AI/ML Education Research

The first research question investigated the development of AI and machine learning in education across publication year, region, and citation influence. While these analyses are somewhat separate from the thematic analysis that follows, they help to provide context for the themes by revealing the general development of AI and machine learning in education over time. The analysis of the number of publications that were published each year in Table 2 reveals that after the year 2021, there was an increase in the interest in AI and data-driven technologies in education.

As Table 2 represents, the number of reviewed publications increased throughout the review period. During 2019 and 2020, only two publications were published each year accounting for 12% of the total number of reviewed publications. From 2021 until 2023, six publications were published each year contributing to 18 studies representing 58% of the total reviewed studies. Furthermore, in 2025, seven studies were published representing 25% of the total number of reviewed articles. The number of published studies in 2024 might represent the delays of publication of articles indexed into the databases utilized for the review of the studies. Finally, AI and machine learning applications in education became more visible after 2021 as a result of the expansion of distance learning in response to the COVID-19 pandemic.

Table 2. Article published per year

Year	Number of articles published	Percentage	Cumulative Percentage
2019	02	06	06
2020	02	06	12
2021	06	19	31
2022	06	19	50
2023	06	19	69
2024	02	06	75
2025	07	25	100
Total	31	100	

Regional Distribution

The geographical distribution of the reviewed studies is presented in Table 3. The regions of Southeast Asia and Europe account for a substantial share of the participants of the reviewed studies. The African and South American regions are represented by considerably fewer studies. The distribution of the regions of the participants indicates that the findings of the reviewed studies cannot be automatically generalized to all regions of the world without further consideration of the regional differences.

The regions of Asia and Europe dominate the field of educational AI and machine learning. The regions of Asia-Pacific, East Asia, South Asia, Southeast Asia, and West Asia are represented by a large share of the studies. The region of North America is represented by three studies. Furthermore, several regions of Asia are represented by only one study each.

The studies that were published from each region are specifically represented by the authors of those studies. Asia-Pacific represents Fahd et al. (2021) and Almalawi et al. (2024). East Asia is represented by authors Wang et al. (2023), Salas-Pilco et al. (2022), and Lin et al. (2023). Eastern Europe is represented by Drugova et al. (2023). North Africa is represented by Sghir et al. (2022). North America is represented by C. Yang et al. (2021), Doleck et al. (2019), and Shemshack and Spector (2020). South Africa and South America are represented by Essa et al. (2023) and De Sousa et al. (2021), respectively. South Asia is represented by authors Hossain (2024), Raj and Renumol (2021), and Khan et al. (2025). Southeast Asia is represented by authors Ramadhan et al. (2023), Hariyanto et al. (2025), Hashim et al. (2022), Shafiq et al. (2022), and Tlili et al. (2021). Europe is represented by authors Lampropoulos (2025), Tudor et al. (2025), Rodrigues et al. (2025), Cuéllar-Rojas et al. (2022), Rodríguez-Ortiz et al. (2025), Liz-Domínguez et al. (2019), and Cuéllar-Rojas et al. (2021). West Africa is represented by author Issah et al. (2023). West Asian authors include Namoun and Alshanqiti (2020), Hardaker and Glenn (2025), and Albreiki et al. (2021).

Table 3. Articles by region

Articles by Region	No of Articles	Percentage	Cumulative Percentage
Asia-Pacific	02	06	06
East Asia	03	10	16
Eastern Europe	01	03	19
North Africa	01	03	22
North America	03	10	32
South Africa	01	03	35
South America	01	03	38
South Asia	03	10	48
Southeast Asia	05	16	64
Southeast Europe	01	03	67
Southeastern Europe	06	20	87
West Africa	01	03	90
West Asia	03	10	100
Total	31	100	

Citation Profile

Citation analysis was retained as a short contextual indicator rather than as a major finding. Table 4 identifies highly cited studies that have influenced research on AI/ML applications in education. The strongest citation attention is associated with intelligent tutoring systems, personalized learning, predictive analytics, and learning analytics, which supports their selection as major thematic areas in the synthesis. However, citation counts were not used as a proxy for study quality.

Citation analysis of the research on machine learning applications in education provides researchers with useful insight into the research (Zhong et al., 2024). By examining the citation counts for research publications in this area, researchers can gain insight into the number of highly influential publications within the field and the level of recognition of those publications by other researchers in the field (Tahamtan & Bornmann, 2019). As can be seen in the cited table (Table 4), there are six research studies that have received a considerable number of citations for their contributions to the research of machine learning in education. The most cited article is that by Lin et al. (2023), with 903 citations. Shemshack and Spector

(2020) is the second most cited article in education with 884 citations. These two publications have garnered nearly 1,800 citations each, indicating their influence on the development of the field. Furthermore, four of the six most cited publications for machine learning in education were published between the years of 2020 and 2023, indicating that the field is still rapidly developing and gaining recognition for new publications at a rapid rate. The majority of the most influential articles in the field have related to topics such as adaptive learning, personalized learning, intelligent tutoring systems, and AI in education. Furthermore, the fact that there are two publications in the year 2023 that have received the highest levels of citations and attention from researchers in the field of education and machine learning indicate that the field is still rapidly developing and gaining recognition for new developments in the research. Overall, therefore, citation analysis of the field of research of machine learning in education indicates that the field is growing in importance for future research in education.

Table 4. The most cited articles related to AI/ML applications in education

Rank	Authors	Year	Citations
1	Lin et al.	2023	903
2	Shemshack & Spector	2020	884
3	Salas-Pilco et al.	2022	485
4	Essa et al.	2023	385
5	Namoun & Alshanjiti	2020	371
6	Albreiki et al.	2021	345

RQ2: Research Design, Sample Characteristics, and Analytical Methods

The second research question relates to the methods used in the research studies in the reviewed literature. Analysis of the type of research performed, the sample sizes used in those studies, and the methods used to analyze the data from those samples reveals the diversity of methods employed by the authors, as well as the limitations of the evidence that is produced by those methods.

Articles by Research Type

Table 5 presents the distribution of the different types of research within the field. The largest group of studies consisted of qualitative research with 17 articles (55%). The second main group consisted of studies that employed quantitative methods with 10 articles (32%). The remaining 4 articles (13%) used mixed methods. Thus, the field is not purely qualitative but also includes quantitative and mixed methods studies. Despite the relatively high number of qualitative studies in the field, there is a need for more quantitative and mixed methods research to test the outcomes of these studies in different educational settings.

Table 5. Articles by research type

Research Types	No of Articles	Percentage	Cumulative Percentage
Mixed	04	13	13
Quantitative	10	32	45
Qualitative	17	55	100
Total	31	100	

Articles by Sample Size

Table 6 presents the distribution of sample sizes used in the 31 studies. The majority of the studies employed small sample sizes; 21 studies (68%) had fewer than 100 participants or cases. Six studies (19%) included between 100 and 500 participants, two studies (6%) included more than 500 participants, and two studies (7%) did not report their sample sizes. Thus, most of the studies were exploratory in nature, and it is beneficial to perform larger studies with AI and machine learning applications to determine if the methods produce benefits for learners alike.

Table 6. Articles by Sample Size

Sample Size	No of Articles	Percentage	Cumulative Percentage
Less than 100	21	68	68
100 - 500	06	19	87
More than 500	02	06	93
Not Specified	02	07	100
Total	31	100	

Articles by Data Analysis Method

Table 7 presents the distribution of data analysis methods. Thematic analysis is the most frequently used method, followed by descriptive, bibliometric, conceptual, and comparative analysis. The total number of analysis methods is 32 rather than 31 because some studies used more than one method for analyzing the data. The dominance of thematic and descriptive analyses reveals the value of qualitative analysis in the field but also indicates the need for more studies employing comparative and statistical analysis of the outcomes of these studies.

Table 7. Articles by data analysis method

Data analysis method	No of Articles	Percentage	Cumulative Percentage
Bibliometric Analysis	03	09	09
Comparative Analysis	01	03	12
Conceptual Analysis	02	06	18
Descriptive Analysis	04	13	31
Thematic Analysis	21	69	100
Total	32	100	

RQ3: Major AI/ML Application Areas and Thematic Synthesis

Predictive Analytics

One of the major applications of AI and machine learning has been in the area of predictive analytics for the education sector (Doleck et al., 2019). The antecedents of implementing AI and machine learning models in education have included the use of student data regarding demographics, educational performance, and learning management systems. The outcomes of implementing such systems have included the ability of educators to recognize at-risk students, to predict whether students will drop out of schools or districts, and to efficiently allocate educational resources to accommodate those at-risk students (Khan et al., 2025; Shafiq et al., 2022).

As shown in Table 8, 28 of the 31 studies included in the review (90%) made reference to the use of predictive analytics. Overall, the studies indicated that there was a relationship between the availability of

data, the use of analytics to model learning, and the support that was provided to the educators to make informed decisions. However, most of the studies did not consider whether the implementation of these analytics models had any impact upon the learning of the students - indicating a potential gap in the relationship between implementing these analytics models and providing educational improvement to the students.

Table 8. Predictive Analytics

Predictive Analytics	No of Articles	Percentage	Cumulative Percentage
Yes	28	90	90
No	03	10	100
Total	31	100	

Personalized Learning

Another major area of application of AI and ML was in the area of personalized learning. For instance, the authors found that AI and ML could be employed to create learning experiences that were tailored to the individual needs of each student (Shemshack & Spector, 2020). Such methodologies have included creating profiles of each student, determining the learning styles of the students, the achievements of each student in completing courses or modules, and even recommending learning content according to those individual analyses of each student (Essa et al., 2023; Hariyanto et al., 2025; Hashim et al., 2022). Table 9 reveals that 27 of the 31 studies (87%) investigated personalized learning in their research. However, in most cases, the studies discussed the implementation of AI and machine learning methodologies in relation to personalized learning as a goal for the learning platforms, yet did not provide evidence in relation to the success of such attempts.

Table 9. Personalized Learning

Personalized Learning	No of Articles	Percentage	Cumulative Percentage
Yes	27	87	87
No	04	13	100
Total	31	100	

Learning Analytics

Learning analytics is the process of measurement, collection, analysis, and reporting of data from learners to understand and optimize the learning processes and environments (Sghir et al., 2022). Most learning analytics studies involve collecting data on learners from a learning environment and using that collected data for specific outcomes such as learner monitoring, feedback, creating learning dashboards for learners and instructors, or even to inform decisions regarding the redesign of a course (Salas-Pilco et al., 2022; De Sousa et al., 2021). As depicted in Table 10, all 31 studies utilized learning analytics in either their primary or supporting applications related to AI and machine learning technologies.

Table 10. Learning Analytics

Learning Analytics	No of Articles	Percentage	Cumulative Percentage
Yes	31	100	100
No	00	00	100
Total	31	100	

Intelligent Tutoring Systems

Intelligent tutoring systems use AI to provide adaptive instruction, feedback, and practice opportunities tailored to learners' needs (Lin et al., 2023). These systems commonly rely on learner modelling, domain

knowledge representation, feedback loops, and adaptive sequencing. Reported outcomes include individualized tutoring, improved engagement, immediate feedback, and support for self-paced learning (Cuéllar-Rojas et al., 2022; Rodrigues et al., 2025). As shown in Table 11, 25 of the 31 studies (81%) addressed intelligent tutoring systems. The evidence is promising, but the literature still needs stronger investigation of teacher integration, learner trust, explainability, and the conditions under which intelligent tutoring improves outcomes beyond traditional support.

Table 11. Intelligent tutoring systems

Intelligent tutoring systems	No of Articles	Percentage	Cumulative Percentage
Yes	25	81	81
No	06	19	100
Total	31	100	

Automated Assessment

Automated assessment reduces teacher workload by supporting scoring, feedback generation, and large-scale evaluation (Wang et al., 2023). The antecedents of automation in education include the use of digital submissions, rubrics, programming and text based tasks, automated feedback systems and models for assessing the performance of the students on these tasks. The outcomes of these systems include the ability to provide feedback to the students at a faster rate, reducing the amount of effort that teachers must dedicate to grading assignments, and increasing the consistency of the grading of certain tasks within the classroom. However, the automation of classroom tasks and assignments is currently limited in its applicability to complex tasks, graphical presentation tasks, code and text based assignments, and those that require open-ended answers from students (Ramadhan et al., 2023; Lampropoulos, 2025). Table 12 indicates that 17 of the 31 studies utilized automated assessment of student assignments, indicating both its importance within the field of educational automation, yet also its lesser prevalence relative to other areas of automation within the classroom.

Table 12. Automated assessment

Automated assessment	No of Articles	Percentage	Cumulative Percentage
Yes	17	55	55
No	14	45	100
Total	31	100	

Table 13 summarizes the thematic synthesis of the five major AI/ML application areas by presenting their antecedents, reported outcomes, conceptual basis, and remaining research gaps.

Table 13. Thematic synthesis of major AI/ML application areas in education

Application area	Antecedents / inputs	Reported outcomes	Conceptual basis and gaps
Predictive analytics	Student records; LMS activity; prior achievement; engagement indicators	At-risk identification; dropout prediction; intervention planning	Based on educational data mining and learning analytics. Gap: prediction is rarely linked to tested interventions or effect sizes.

Application area	Antecedents / inputs	Reported outcomes	Conceptual basis and gaps
Personalized learning	Learner profiles; prior performance; preferences; adaptive content rules	Engagement; learner autonomy; targeted resources	Based on adaptive and learner-centered learning. Gap: limited longitudinal evidence and weak reporting of personalization mechanisms.
Learning analytics	Clickstream data; assessment data; attendance; interaction logs	Dashboards; monitoring; feedback; course redesign	Based on data-informed decision-making. Gap: privacy, ethics, and actionability remain underdeveloped.
Intelligent tutoring systems	Learner models; domain models; feedback rules; adaptive sequencing	Immediate feedback; individualized tutoring; self-paced learning	Based on cognitive tutoring and adaptive instruction. Gap: more evidence is needed on teacher integration, trust, and explainability.
Automated assessment	Digital submissions; rubrics; scoring algorithms; feedback models	Faster grading; scalable feedback; consistency for structured tasks	Based on assessment for learning. Gap: complex reasoning, fairness, bias, and transparency need further study.

Discussion

The findings answer the three research questions and show that AI/ML in education is expanding, but the evidence base remains uneven in methods, geography, and depth of evaluation.

For RQ1, the publication activity in the topic area has generally increased since 2021 and is primarily concentrated in Asian and European regions of the world. There has been an increase in the use of digital learning, learning data management systems, and AI-enabled educational technologies following the COVID-19 pandemic. Thus, the majority of the research findings may not be representative of educational systems that lack the digital infrastructure to utilize these technologies.

For RQ2, there is diversity in the methods employed by the studies, with the majority of studies being qualitative in nature. However, there are also quantitative and mixed methods studies within the review. Furthermore, the majority of the studies utilized small samples of review-based evidence, limiting their conclusions. Consequently, there is a need for more empirical research within the area, utilizing larger samples and providing more detailed information regarding the data and algorithms used in the studies, as well as the educational outcomes of those studies.

For RQ3, five major application areas emerged: predictive analytics, personalized learning, learning analytics, intelligent tutoring systems, and automated assessment. These areas are connected but not isolated from one another. For instance, learning analytics can feed data into systems that enable prediction and personalization; prediction can allow for the identification of students who may need additional support; personalized learning and intelligent tutoring systems can provide such support; and automated assessment can provide feedback. However, most studies are focused on the potential for artificial intelligence and machine learning techniques to be applied within these areas, rather than evaluating how the application of these methods to learning and education has actually led to improvements in learning outcomes, reducing learning inequities, or improving other aspects of the learning process related to student or teacher privacy.

Theoretically, this review suggests that AI and machine learning in education should be studied through the lenses of learning analytics, adaptive learning, assessment for learning, and ethical AI. While many studies

do discuss in what ways the technologies can be applied to education, there is little discussion of the theoretical framework of the research. Future studies should consider including discussions of the theoretical frameworks of the research in relation to concepts like learning and cognition, motivation, and the roles of teachers and administrators in educational settings.

Limitations and Future Research

Several limitations should be noted in this review. First, the study was limited to English-language articles that were published within the period between 2019 and 2025. Second, while a variety of research studies were reviewed, the majority of those studies utilized small samples of participants, relied upon other research review studies as the basis for their publications, or performed limited testing of the algorithms that were proposed within those research projects. Third, the majority of AI studies were represented by samples from regions like Asia, Europe, and North America, and there were limited studies from regions like Africa, South America, and others. Furthermore, while a narrative review of the studies was performed, a more detailed meta-analysis of those articles with the calculation of the effect sizes of the studies was not performed due to the differences in the research designs of those publications. Finally, due to the relatively new nature of AI technologies, there are still emerging issues regarding AI that require investigation, such as explainable AI, emotion recognition, recommendation systems, culturally responsive AI, and issues related to privacy, bias, and accountability. Future studies in the area of AI should utilize larger and more diverse samples, employ longitudinal study designs or intervention designs, utilize more transparency in the algorithms that are implemented by those studies, and address issues related to the ethics of AI systems altogether.

Implications

The findings have implications for educators, policymakers, educational researchers, and the developers of educational technology. Educators may find value in using the tools of predictive and learning analytics to determine which students may require additional support in their education, but cannot replace teachers' ability to understand each student. Policymakers may utilize these findings to develop policies regarding data privacy, transparency, and fairness in AI-enabled education. Finally, the developers of educational technology may find value in incorporating elements of explainable and inclusive technologies that support educational goals, rather than focusing upon the accuracy of educational automation tools.

Conclusions

A PRISMA-guided systematic review of 31 studies on AI and machine learning applications in education from 2019 to 2025 has revealed five major areas of application, including predictive analytics, personalized learning, learning analytics, intelligent tutoring systems, and automated assessment. The results of this review indicate that AI and machine learning technologies have the potential to significantly aid education in areas such as early warning systems, personalized learning, learning analytics, and assessment. However, most studies that have been published on these technologies have exhibited limitations in terms of sample sizes, geographical representation of study populations, theoretical grounding, study quality appraisal, and the availability of empirical evidence from large-scale projects. The future values of AI and machine learning in the field of education will likely depend upon factors beyond the technological capabilities of

these systems, such as educational design, ethics, teacher involvement, learner privacy, and the ability of these technologies to improve educational outcomes.

References

- Albreiki, B., Zaki, N., & Alashwal, H. (2021). A systematic literature review of student performance prediction using machine learning techniques. *Education Sciences*, 11(9), 552. <https://doi.org/10.3390/educsci11090552>
- Almalawi, A., Soh, B., Li, A., & Samra, H. (2024). Predictive models for educational purposes: A systematic review. *Big Data and Cognitive Computing*, 8(12), 187. <https://doi.org/10.3390/bdcc8120187>
- Cuéllar-Rojas, O., Hincapié, M., Contero, M., & Güemes-Castorena, D. (2021). Intelligent tutoring system: A bibliometric analysis and systematic literature review. *Research Square*. <https://doi.org/10.21203/rs.3.rs-673038/v1>
- Cuéllar-Rojas, O., Hincapié-Montoya, M., Contero, M., & Güemes-Castorena, D. (2022). Bibliometric analysis and systematic literature review of intelligent tutoring systems. *Frontiers in Education*, 7. <https://doi.org/10.3389/educ.2022.1047853>
- De Sousa, E. B. G., Alexandre, B., Mello, R. F., Falcão, T. P., Vesin, B., & Gašević, D. (2021). Applications of learning analytics in high schools: A systematic literature review. *Frontiers in Artificial Intelligence*, 4, 737891. <https://doi.org/10.3389/frai.2021.737891>
- Doleck, T., Lemay, D. J., Basnet, R. B., & Bazalais, P. (2019). Predictive analytics in education: A comparison of deep learning frameworks. *Education and Information Technologies*, 25(3), 1951-1963. <https://doi.org/10.1007/s10639-019-10068-4>
- Drugova, E., Zhuravleva, I., Zakharova, U., & Latipov, A. (2023). Learning analytics driven improvements in learning design in higher education: A systematic literature review. *Journal of Computer Assisted Learning*, 40(2), 510-524. <https://doi.org/10.1111/jcal.12894>
- Essa, S. G., Celik, T., & Human-Hendricks, N. E. (2023). Personalized adaptive learning technologies based on machine learning techniques to identify learning styles: A systematic literature review. *IEEE Access*, 11, 48392-48409. <https://doi.org/10.1109/access.2023.3276439>
- Fahd, K., Venkatraman, S., Miah, S. J., & Ahmed, K. (2021). Application of machine learning in higher education to assess student academic performance, at-risk, and attrition: A meta-analysis of literature. *Education and Information Technologies*, 27(3), 3743-3775. <https://doi.org/10.1007/s10639-021-10741-7>
- Hardaker, G., & Glenn, L. E. (2025). Artificial intelligence for personalized learning: A systematic literature review. *International Journal of Information and Learning Technology*, 42(1), 1-14. <https://doi.org/10.1108/ijilt-07-2024-0160>

- Hariyanto, Kristianingsih, F. X. D., & Maharani, R. (2025). Artificial intelligence in adaptive education: A systematic review of techniques for personalized learning. *Discover Education*, 4(1). <https://doi.org/10.1007/s44217-025-00908-6>
- Hashim, S., Omar, M. K., Jalil, H. A., & Sharef, N. M. (2022). Trends on technologies and artificial intelligence in education for personalized learning: Systematic literature review. *International Journal of Academic Research in Progressive Education and Development*, 11(1). <https://doi.org/10.6007/ijarped/v11-i1/12230>
- Hossain, R. (2024). Prospective artificial intelligence (AI) applications in the university education level: Enhancing learning, teaching and administration through a PRISMA base review systematic review. *Pakistan Journal of Life and Social Sciences*, 22(2). <https://doi.org/10.57239/pjlss-2024-22.2.00694>
- Issah, I., Appiah, O., Appiahene, P., & Inusah, F. (2023). A systematic review of the literature on machine learning application of determining the attributes influencing academic performance. *Decision Analytics Journal*, 7, 100204. <https://doi.org/10.1016/j.dajour.2023.100204>
- Khan, S., Mazhar, T., Shahzad, T., Khan, M. A., Waheed, W., Waheed, A., & Hamam, H. (2025). Predictive analytics in education-enhancing student achievement through machine learning. *Social Sciences & Humanities Open*, 12, 101824. <https://doi.org/10.1016/j.ssaho.2025.101824>
- Lampropoulos, G. (2025). Augmented reality, virtual reality, and intelligent tutoring systems in education and training: A systematic literature review. *Applied Sciences*, 15(6), 3223. <https://doi.org/10.3390/app15063223>
- Landis, J. R., & Koch, G. G. (1977). The measurement of observer agreement for categorical data. *Biometrics*, 33(1), 159-174. <https://doi.org/10.2307/2529310>
- Lin, C., Huang, A. Y. Q., & Lu, O. H. T. (2023). Artificial intelligence in intelligent tutoring systems toward sustainable education: A systematic review. *Smart Learning Environments*, 10(1). <https://doi.org/10.1186/s40561-023-00260-y>
- Liz-Domínguez, M., Caeiro-Rodríguez, M., Llamas-Nistal, M., & Mikic-Fonte, F. A. (2019). Systematic literature review of predictive analysis tools in higher education. *Applied Sciences*, 9(24), 5569. <https://doi.org/10.3390/app9245569>
- Namoun, A., & Alshantiti, A. (2020). Predicting student performance using data mining and learning analytics techniques: A systematic literature review. *Applied Sciences*, 11(1), 237. <https://doi.org/10.3390/app11010237>
- Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., McGuinness, L. A., Stewart, L. A., Thomas, J., Tricco, A. C., Welch, V. A., Whiting, P., & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ*, 372, n71. <https://doi.org/10.1136/bmj.n71>

- Raj, N. S., & Renumol, V. G. (2021). A systematic literature review on adaptive content recommenders in personalized learning environments from 2015 to 2020. *Journal of Computers in Education*, 9(1), 113-148. <https://doi.org/10.1007/s40692-021-00199-4>
- Ramadhan, A., Warnars, H. L. H. S., & Razak, F. H. A. (2023). Combining intelligent tutoring systems and gamification: A systematic literature review. *Education and Information Technologies*, 29(6), 6753-6789. <https://doi.org/10.1007/s10639-023-12092-x>
- Rodrigues, B., Pinto, R., & Gonçalves, G. (2025). A systematic literature review of AI-driven intelligent tutoring systems in engineering education: Emphasizing personalization, feedback, and student monitoring. *IEEE Access*, 13, 190152-190177. <https://doi.org/10.1109/access.2025.3626473>
- Rodríguez-Ortiz, M. Á., Santana-Mancilla, P. C., & Anido-Rifón, L. E. (2025). Machine learning and generative AI in learning analytics for higher education: A systematic review of models, trends, and challenges. *Applied Sciences*, 15(15), 8679. <https://doi.org/10.3390/app15158679>
- Salas-Pilco, S., Xiao, K., & Hu, X. (2022). Artificial intelligence and learning analytics in teacher education: A systematic review. *Education Sciences*, 12(8), 569. <https://doi.org/10.3390/educsci12080569>
- Sghir, N., Adadi, A., & Lahmer, M. (2022). Recent advances in predictive learning analytics: A decade systematic review (2012-2022). *Education and Information Technologies*, 28(7), 8299-8333. <https://doi.org/10.1007/s10639-022-11536-0>
- Shafiq, D. A., Marjani, M., Habeeb, R. A. A., & Asirvatham, D. (2022). Student retention using educational data mining and predictive analytics: A systematic literature review. *IEEE Access*, 10, 72480-72503. <https://doi.org/10.1109/access.2022.3188767>
- Shemshack, A., & Spector, J. M. (2020). A systematic literature review of personalized learning terms. *Smart Learning Environments*, 7(1). <https://doi.org/10.1186/s40561-020-00140-9>
- Tahamtan, I., & Bornmann, L. (2019). What do citation counts measure? An updated review of studies on citations in scientific documents published between 2006 and 2018. *Scientometrics*, 121(3), 1635-1684. <https://doi.org/10.1007/s11192-019-03243-4>
- Tlili, A., Chang, M., Moon, J., Liu, Z., Burgos, D., Chen, N. S., & Kinshuk. (2021). A systematic literature review of empirical studies on learning analytics in educational games. *International Journal of Interactive Multimedia and Artificial Intelligence*, 7(2), 250-261. <https://doi.org/10.9781/ijimai.2021.03.003>
- Tudor, I., Dlab, M. H., & Hoić-Božić, N. (2025). Personalized learning in secondary and higher education: A systematic literature review of technology-enhanced approaches. *International Journal of Educational Methodology*, 11(3), 359-375. <https://doi.org/10.12973/ijem.11.3.359>
- Wang, H., Tlili, A., Huang, R., Cai, Z., Li, M., Cheng, Z., Yang, D., Li, M., Zhu, X., & Fei, C. (2023). Examining the applications of intelligent tutoring systems in real educational contexts: A systematic literature review from the social experiment perspective. *Education and Information Technologies*, 28(7), 9113-9148. <https://doi.org/10.1007/s10639-022-11555-x>

Yang, C., Chiang, F., Cheng, Q., & Ji, J. (2021). Machine learning-based student modeling methodology for intelligent tutoring systems. *Journal of Educational Computing Research*, 59(6), 1015-1035. <https://doi.org/10.1177/0735633120986256>

Zhong, Z., Guo, H., & Qian, K. (2024). Deciphering the impact of machine learning on education: Insights from a bibliometric analysis using bibliometrix R-package. *Education and Information Technologies*, 29(16), 21995-22022. <https://doi.org/10.1007/s10639-024-12734-8>