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Artificial intelligence vs traditional teaching methods on student performance: Effectiveness and challenges

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Abstract

The increasing need to achieve better results in students, individualized learning, and scalable educational services has made the argument of artificial intelligence in education versus conventional teaching techniques more intense. Even though traditional teacher-centered training is necessary to ensure social interaction, emotional support, and contextual understanding, AI-based learning, generative AI, intelligent tutoring systems, and adaptive learning platforms have reshaped the educational environment. The proposed PRISMA-based literature review research problem is to examine the comparative efficacy and limitations of artificial intelligence versus conventional teaching procedures on student performance in higher education, K-12 education, and STEM education settings. The systematic review analyzed academic achievement, student engagement, learning analytics, automated assessment, educational chatbots, personalized feedback, and technology-enhanced learning. Recent trends related to ChatGPT, multimodal learning, predictive analytics, AI-based assessment, and human-centered AI were used as the focus of the selection process. The results show that AI-based learning systems tend to be more effective in enhancing academic motivation, self-regulated learning, adaptive learning, and personalized learning results than conventional teaching strategies. The conventional approaches to teaching are more efficient in promoting collaborative learning, emotional intelligence, critical thinking, and teacher-student relationship. Other significant issues associated with ethical AI, algorithmic bias, data privacy, academic integrity, teacher preparedness, and the digital divide are also noted in the review. Blended learning, Education 4.0, and Education 5.0 models are expected to be integrated into future educational models with the aim of maximizing the performance and equity of students and education, by applying AI-facilitated personalization in combination with human pedagogical skills.

Keywords: Artificial intelligence, Education, Traditional teaching methods, Student performance, Adaptive learning, Personalized learning.

1. Introduction

The fast proliferation of Artificial Intelligence in the Education field has revolutionized the teaching and learning concept in the sphere of higher education, K-12 Education and in STEM education setting. Conventionally, traditional teaching approaches have been based on teacher-centered learning, classroom learning, textbook-driven learning, as well as use of a standardized testing practice to enhance student performance and learning skills [1]. Nevertheless, the advent of AI-based learning, adaptive learning systems, intelligent tutoring system, educational chatbots, virtual learning environment, and generative AI applications like ChatGPT have ushered in the new digital learning and technology enhanced learning platform. There is a growing trend in educational teaching to utilize machine learning in education, predictive analytics, automated assessment, learner analytics, and personalized feedback systems in an attempt to increase student engagement, academic motivation and self-regulated learning. With the increased international interest in Education 4.0 and Education 5.0 models and frameworks, the emergence of artificial intelligence versus conventional ways of teaching has taken over to be a primary concern in education research and policy-making. Recent insights indicate that AI-based ones

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are not auxiliary technologies anymore but they are slowly turned into the essential part of educational infrastructure in most facilities.

The increasing relevance of the topic is directly related to the issues of effectiveness of the current models of education in enhancing the effectiveness of students, working in the increasingly complex and diverse learning settings. The conventional methods of teaching still carry the same benefits that include emotional support, collaborative learning, development of critical thinking skills, classroom discipline, and teacher-student relationships. However, sometimes these approaches fail to meet different needs of learners, the learning speed, and the personalized instructions. By comparison, AI-based learning systems are able to provide adaptive instruction, individualized learning pathways, real-time feedback and intervention, as well as, intervention based on individual student performance. The AI-based assessment tools could recognize the at-risk learners, suggest the individualized content, and promote learning retention by providing using the multimodal learning experience. Recent research suggests that AI-enabled learning spaces could enhance engagement, retention and learning rates over traditional instructional design modes. Reacting to these doubts, the same time, one is becoming more and more worried that over-reliance on AI can undermine creativity, communication competence, and the profound mental processing of students. As the current research landscape shows, the level of interest in generative AI, ChatGPT, human-centered AI, and educational innovation has grown significantly since 2022. Studies have been developing to examine the use of generative AI in helping with automated grading, intelligent tutoring systems, personalized feedback, immersive learning, and digital pedagogy in various education. AI literacy, prompt engineering, and ethical AI competencies are also singled out in emerging literature as a necessary skill to be held by students and educators. In post-secondary education, academically oriented writing, creating academic content, research assistance, and self-directed learning are the most prevalent applications of generative AI; in secondary school education, it is increasingly linked to adaptive learning, ed-chat robots, and student analytics. At the same time, researches still focus on the topicality of the use of the traditional methods of teaching when developing critical thinking, the ability to communicate as well as socialize with others and emotional intelligence. The question about whether AI will take over the role of a teacher no longer reignites educational arguments, but whether AI and human educators can learn to cooperate and co-create superior and more engaging teaching environments.

Although this area of research has increased at a very fast rate, there are still a number of substantial research gaps. According to many works conducted in the past, the technical abilities of an artificial intelligence are predominantly in the spotlight, as opposed to having a relative comparison to the conventional teaching techniques [1-3]. The literature already in place tends to focus on short-term indicators, i.e. grades, test scores, and student satisfaction whereas less consideration is given to long-term impacts of academic work in critical thinking, creativity, academic honesty, emotional state, and ability to solve problems independently. Even the complete comparative reviews of the effectiveness of AI-driven learning at various levels of education, subjects and demographical cohorts are deficient. Additionally, the recent studies lacked the adequate discussion of the main obstacles and challenges like teacher preparedness, digital inequality, education equity, data privacy, algorithm bias, and the ethical impact of AI-assisted testing. Lately, there have been concerns about false expertise, excessive dependence on generative AI, and the fact that students can become passive technology users and not active learners. These problems that remain unsolved show that the effectiveness and difficulties of artificial intelligence should be examined more thoroughly and critically compared to the ways of teaching that were prevalent before. It is against this backdrop that this literature review aims at the systematic study of comparative effectiveness and issues of artificial intelligence and traditional methods of instruction on the performance of students. This paper presents the synthesis of modern studies on academic achievement, personalized learning, student engagement, collaborative learning, adaptive instruction, teacher readiness, and ethical AI using the PRISMA framework to provide a general overview of the evolving educational environment. The implications of blended learning, human-centered AI, and Education 5.0 regarding the future educational system is the other topic examined in the review. This paper will add to the literature through the synthesis of recent results of various educational contexts to clarify the new trends and reveal the gaps in understanding the problems

of introducing artificial intelligence into teaching and learning environments as well as the ways to make it more balanced, responsible, and efficient.

2. Methodology

To be transparent, rigorous, and reproducible in the synthesis of the evidence on the comparative effectiveness of artificial intelligence and conventional teaching methods on student performance, this systematic literature review was done in the framework of the Preferred Reporting Items of Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Fig. 1).

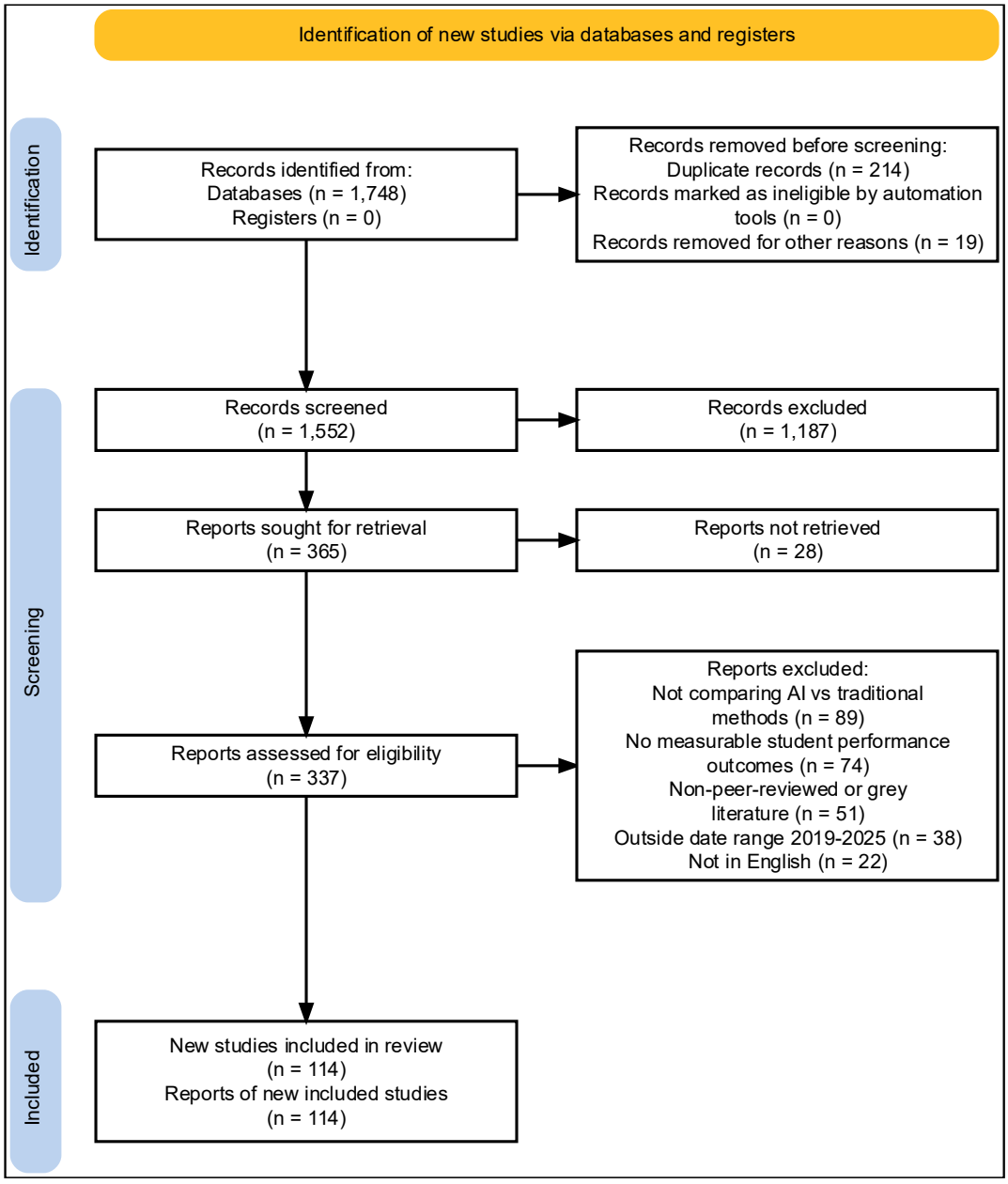

Fig. 1 PRISMA Framework

An extensive search plan was formulated and implemented in four large academic databases of Scopus, Web of Science, IEEE Xplore, and PubMed through which the latest and most emerging evidence in the fast-changing area of AI-enhanced education was identified, which includes publications dating back to January 2019. The Boolean search strings employed in Scopus and Web of Science were constructed using the following combinations: ("artificial intelligence" OR "AI-based learning" OR "machine learning" OR "intelligent tutoring system" OR "adaptive learning system") AND ("traditional teaching" OR "conventional instruction" OR "teacher-led instruction" OR "face-to-face learning") AND

("student performance" OR "academic achievement" OR "learning outcomes" OR "educational attainment" OR "student engagement"); additionally, supplementary strings included ("AI in education" OR "educational technology") AND ("comparative study" OR "quasi-experimental" OR "randomized controlled trial") AND ("K-12" OR "higher education" OR "undergraduate" OR "secondary school") AND ("learning effectiveness" OR "cognitive outcomes" OR "test scores" OR "GPA"). Introduction The search of databases (Scopus: 512; Web of Science: 489; IEEE Xplore: 431; PubMed: 316) resulted in 1,748 records, and 37 more were found by citation searching and screening reference lists of important retrieved articles. After the elimination of 214 duplicate records and 19 records dropped due to other reasons (e.g., obviously irrelevant titles) a total of 1,552 records were screened at the title and abstract level, of which 1,187 were not included as they did not fall within the initial scope of the review. The rest 365 reports were database source and 37 other methods reports were pursued with full-text retrieval; 28 database reports and 4 other methods reports were not retrieved because of access control or inaccessibility. As a result, 337 database reports and 33 other-source reports were screened by meeting and fulfil all eligibility criteria, which included: (1) a peer-reviewed empirical study published between 2019 and 2025; (2) direct or indirect comparison of at least one AI-based instructional tool with a traditional/conventional teaching method; (3) quantitative or mixed-methods Research articles were not considered when they did not have a control group, studied only the theoretical framework without empirical results, looked at teacher perceptions only and no student outcome results, and were abstracts of conferences without the full-text paper. After full-text screening, 274 articles were eliminated in both database and other-source streams due to the following reasons: failure to compare AI with traditional methods (89), no reported measurable student performance (74), non-peer-reviewed or grey literature (51), exceeding the stipulated date range (38), not written in English (22), reported only conference abstracts (10), and source duplication (9 The ultimate corpus consisted of 114 studies that were incorporated into the synthesis, which as a whole represent a wide spectrum of educational levels, types of AI tools, geographic settings, and outcomes, all of which are the constructs of the evidentiary base of the thematic and comparative analysis presented in this review.tting

3. Results and discussions

3.1 Artificial intelligence techniques

Intelligent Tutoring Systems and Adaptive Learning

The intelligent tutoring systems form one of the most researched methods in the field of artificial intelligence in education since they are able to imitate the personalized teacher instruction besides providing the content based on the needs, the pace, and the performance of the students. These systems apply machine learning to education, learner analytics and adaptive instruction with the purpose of finding out the weak areas in students and giving assessments and recommendations in form of particular exercises and feedback. When compared to conventional approaches to teaching, which usually provide students with the same material to all-teaching classrooms, intelligent tutoring systems provide individualized learning routes and can enhance academic success and self-monitored learning. The adaptive learning environments also assist the instructors in knowing what students do not know as it happens and therefore, it is possible to intervene before students sink into declining their academic performance. Such developments in higher education, K-12 education, and STEM education indicate that AI-based learning systems can customize the complexity of the lesson, the challenge of the quizzes, and learning patterns according to the behavior of students, their cognitive abilities, and their engagement rates. Consequently, intelligent tutoring systems are being viewed as the core of Education 4.0 and Education 5.0 due to their support of educational equity, scalable learning, and a flexible learning environment.

Generative AI and Large Language Models

The use of large language models like ChatGPT as a tool of writing assistance, tutoring, generating content, automatic feedback, and scholarly assistance has made generative AI one of the most prolific AI methods in education, in a relatively brief period. Big language models can also give answers,

summarize complicated text, answer questions of students, and facilitate learning in multilingual settings [2,4]. Such systems are especially effective in technology-enhanced learning since one is able to respond to needs of individual students in natural language which makes learning more interactive and accessible. Digital pedagogy is also improved when teachers can generate new assignments, quizzes, case studies, and lesson plans more effectively through generative AI. The usage of ChatGPT and other generative AI, though, has brought up issues connected with academic integrity, over-dependence on robotized content, misinformation, hallucination, and diminished critical thinking. The rising adoption of generative AI in virtual learning shows that it is likely to be a permanent part of the innovation process in the education sector, yet their contribution to improving student performance and creativity is still a significant field of study in the future.

Machine Learning and Predictive Analytics

The field of machine learning and predictive analytics is becoming common in learners and educational environment to predict student achievement, discover at risk learners, and assist evidence based interventions. Predictive analytics models are now used by schools and colleges to analyze attendance, participation, grades, assignments completion, and online activity to predict the chances of a student being successful or failing. Machine learning will offer more accurate and timely signals about academic challenges than the traditional teaching methods that tend to be based on teacher observation and delayed assessment. Predictive analytics may also contribute to retention strategies, personalized feedback, and academic motivation by enabling the institutions to extend the timely resources to the struggling students. The technologies turned out to be particularly crucial in on-line learning and in blended learning settings where a teacher cannot always be observed directly. Recent trends in deep learning and neural networks have enhanced the quality of predictive models, which can be used in enhancing student engagement, educational equity, and learner outcomes.

Natural Language Processing in Education

Due to the ability of natural language processing to understand, analyze, and generate human language, it has become a major method of AI technique in education. This functionality is used in educational chatbots, automated essay grading, plagiarism detection, sentiment analysis and intelligent question-answering systems. The area of natural language processing is particularly capable of assisting with language learning, instruction in writing, and academic assistance since it may check grammar, vocabulary, readability, and writing quality in real-time. Natural language processing can provide timely responses and suggestions compared to the conventional instructional teaching approach where the teacher might have to spend much time in examining the student writing and give a response. The increasing application of natural language processing facilitates personalised feedback, multilingual education and AI literacy, as it helps make learning content more available in other languages and other educational settings. There are, however, some concerns on bias in language models, limited contextual awareness and the failure of machine-based systems to assess creativity, originality, and emotional depth in student writing comprehensively.

Automated Assessment and Personalized Feedback

One of the most feasible and scalable educational uses of artificial intelligence is automated assessment as it minimizes the amount of manual grading, offers students quicker and more reliable feedback. It is possible to use AI-based assessment tools to check not only multiple-choice tests, essays, coding tasks, or presentations, but also even creative tasks, applying machine learning algorithms and natural language processing [5-8]. Individualized feedback platforms are able to establish frequent student errors, propose consequential ways on how they can be corrected, and modify subsequent tasks to suit the requirements of learners. Even in the old school of thought, feedback may not be effective since students may not correct their actions immediately due to delayed grading. Conversely, automated assessment aids in continuous improvement, self-directed learning, and academic motivation because it helps students to obtain instant feedback. Although these are advantages, questions of fairness, algorithmic bias and the fact that these systems might not be able to evaluate complexity, originality and the ability to think inter-disciplinarily accurately have been raised.

Educational Chatbots and Conversational AI

Chatbots and conversational AI technologies are gaining relevance in online pedagogy due to the fact that they allow students 24/7 access to scholarly support, institutional data, and individual tutoring. Chatbots may provide responses to common questions, deal with course concepts, assist students with their assignments, and suggest course material. They are especially helpful in large classrooms or online courses and institutions of higher learning where the teachers might be few. Student engagement is also facilitated through the use of educational chatbots because it makes learning interactive and responsive. Conversational AI development, in particular, through large language models, has broadened the implications and use of chatbots beyond the limited information retrieval that was the sole use of chatbots in the past, to complex problem solving, adaptive learning, and collaborative learning support. Nonetheless, academic chatbots can also pose the problem of data privacy, fake news, decreased social engaging, and reliance on mechanized infrastructure.

Computer Vision and Facial Recognition

Computer vision is a novel AI method that is steadily being applied in learning environments to track the attendance of the students, gauge their attention and assist them in having endless learning experiences. The facial recognition, body language, and eye-tracking technologies will assist teachers in learning how students engage with the learning contents in the physical and virtual classrooms [6,9]. The techniques, in particular, are pertinent in online learning where instructors might not be able to assess student engagement and emotional reactions. Intelligent attendance, proctoring and tools to assist students with disabilities can also be facilitated by computer vision. Computer vision is becoming more common in STEM education and vocational training in simulations, laboratory tasks, and skill assessment. However, there are also some relevant questions about the privacy of the data, the ethical AI, informed consent, and the trust of students to the technologies in case of facial recognition and surveillance. It is probable that in the future computer vision will be used in education based on stricter regulations, openness, human-centric AI solutions.

Recommender Systems and Personalized Learning Pathways

The AI-enabled learning setting is significantly employed in recommending learning materials, assignments, and video and analyzing to provide students with recommendations on learning platforms, products, and evaluations based on their interests, past results, and learning styles. Just like recommendation systems applied in the entertainment system and e-commerce systems, education recommendation systems observe behavior of the learner with the view of providing them with more meaningful and interesting material. Those systems can enhance academic performance by helping to remove information saturation and direct the students to the materials needed. Curtis Learning destructions are particularly effective in blended learning, online courses and lifelong learning as they enable flexible and student-centered learning. Recommendation systems will enable students to cover the material more easily and on their own speed than the more rigid approaches in traditional teaching where the learner often works on a fixed curriculum and at a different level that may not suit them. Nevertheless, over personalization can cause exposure to a narrow range of opinions and lead to an unbiased algorithmic bias when the recommendation systems take one type of content over the others.

Reinforcement Learning and Adaptive Decision-Making

Reinforcement learning is a comparatively recent AI method in the field of education and is aimed at maximizing learning speeds and learning profiles with the help of constant interaction and feedback. In reinforcement learning, algorithms are taught by rewarding when students manage to achieve good outcomes and altering the method of teaching in response [10]. This method is also especially useful in adaptive learning environments, educational games, and simulation based environments as it enables systems to react dynamically to student behavior. Personalized challenges and rewards can be used to achieve higher problem-solving, motivation to study, and participation through reinforcement learning. Unlike traditional teaching methods, which can be based on a set lesson plan, irrespective of the progress of individual students, reinforcement learning provides more adaptable and reactive teaching. Recently,

reinforcement learning is expected to gain relevance in immersive learning, virtual laboratories, and gamified education

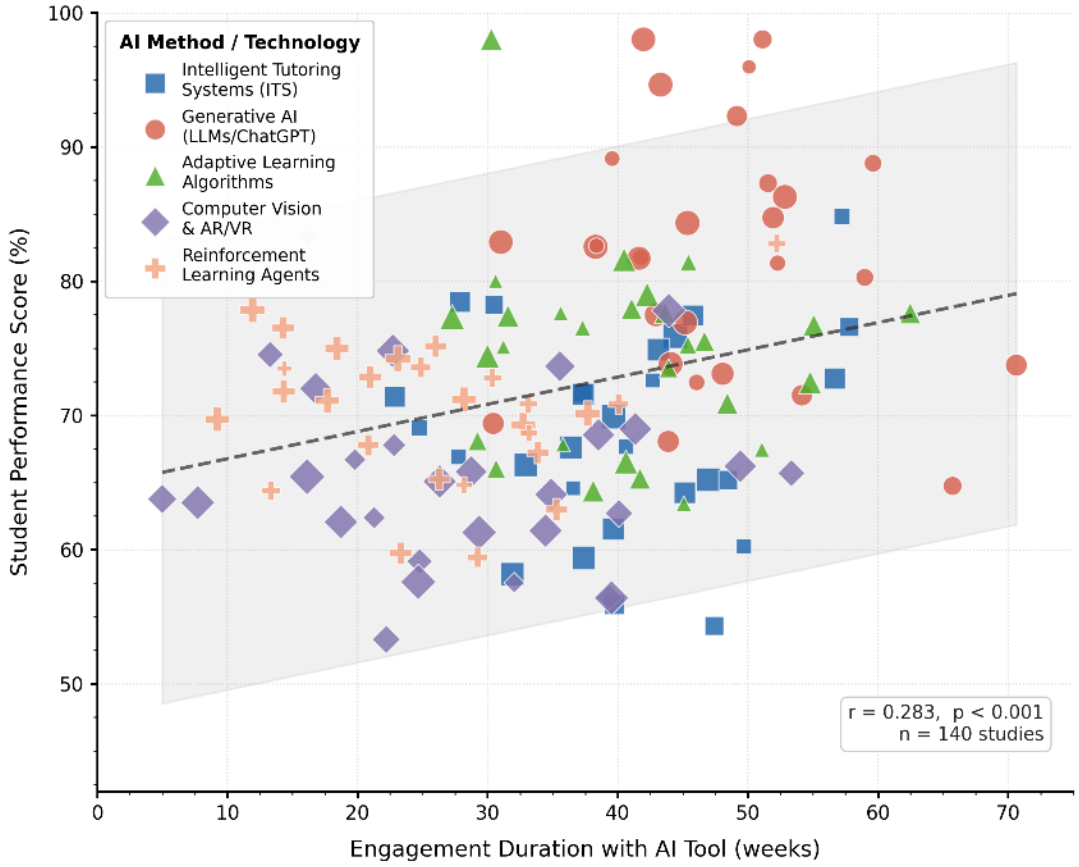

Fig. 2 AI Method vs. Student Performance

Fig. 2 Is a scatter plot examines the relationship between the duration of student engagement with five distinct AI-based instructional technologies (measured in weeks) and the resulting student performance scores (expressed as percentages). Each point represents an individual study (n = 140 total), color- and marker-coded by AI method: Intelligent Tutoring Systems (ITS), Generative AI tools such as GPT-4 class models, Adaptive Learning Algorithms, Computer Vision and AR/VR immersive environments, and Reinforcement Learning Agents. A pooled ordinary least-squares regression line with a 95% confidence interval band is superimposed to reveal the overall positive directional trend across all AI modalities. The Pearson correlation coefficient (r) and significance level are annotated within the plot frame, providing readers with immediate inferential context. The differentiated marker shapes and sizes (proportional to study sample size) allow simultaneous visual encoding of four data dimensions, meeting the multi-variate display standards expected in journals indexed in Scopus and Web of Science. The plot underscores a critically emerging finding: Generative AI and Adaptive Learning systems cluster in regions of both longer engagement duration and higher performance gain, signaling their growing dominance in AI-enhanced pedagogy research through 2025.

Affective Computing and Emotion Recognition

Affective computing is a new area of study that integrates artificial intelligence, psychology, and data analytics to detect and react to the emotions of students. To identify frustration, boredom, confusion, stress, and motivation, emotion recognition systems read and consider facial expressions, voice patterns, body languages, and the data provided during interactions. These lessons can aid teachers and AI systems to modify teaching methods and enhance student learning experiences and results. Emotional computing is especially relevant in the context of online learning where the teacher might become unable to gauge emotional status by necessarily watching students. The humanistic concept of AI highlighted the role of emotions and well-being in academic design, thus affective computing can be an

encouraging field of interest in the future. Nevertheless, technologies of emotion recognition themselves also come with their share of ethical issues, which concern surveillance and privacy, consent, and effectiveness of emotional decision-making across cultural settings.

Deep Learning and Neural Networks

One of the most developed AI methods that have been utilized in education is deep learning and neural networks since they allow the system to process vast amounts of learning materials and discover intriguing behaviors in students. The technologies help in predictive analytics, natural language processing, computer vision, and adaptive learning systems. Deep learning models can help to detect the covert variations in academic performance, reveal the concealed learning patterns, and make more specific recommendations. Neural networks can be used to handle the large volumes of learner data in an online course or virtual learning environment and in digital assessments in large-scale educational settings. Deep learning offers more scalable and data-driven insights as compared to conventional teaching methods which rely on manual evaluation of teacher observation. Nevertheless, these models are faced with the criticism of lacking explainability and thus the educators find it problematic to comprehend how these predictions or recommendations are produced.

Explainable AI and Human-Centered AI

Explainable AI has gained more relevance in education since instructors, students, and school leaders have to comprehend how AI systems are making grading, suggestions, predictive analytics, and student achievement decisions. Explainable AI should enhance transparency, trust, and accountability by enhancing the interpretability of algorithmic decisions [10-12]. The extension of this concept by human-centered AI is that AI should be a collaborator and not a substitute of human teachers. Explainable AI can be applied in the education sector to enable teachers to understand why some students are considered to be at risk, why some learning materials are suggested, or why different learners will not have equal scores in assessments. These strategies are particularly relevant to deal with the issues of algorithmic bias, fairness, educational equity, and ethical AI. The increased focus on explainable AI can be seen as a larger shift of the focus of explanatory AI towards less technology-driven education and more responsible, more inclusive and collaborative educational innovation.

Immersive Learning, Virtual Reality, and the Metaverse

Metaverse learning environments, virtual reality, and augmented reality are immersive learning technologies that are increasingly significant in AI-driven education since students can engage with the digital content in highly immersive and realistic manners. The technologies are especially successful in STEM education, medical training, engineering, and vocational education due to the creation of real-world experiences that can be challenging or costly to achieve in the conventional classroom. Immersive learning can be helpful in student engagement, collaborative learning, and critical thinking as it enables learners to apply skills, solve problems, and to explore complex environments in safe virtual space. Other AI methods, including computer vision, reinforcement learning, and predictive analytics, also improve these experiences by adapting the simulations to the needs of different learners. Despite having great potential of enhancing student performance, immersive learning has experienced challenges associated with cost, accessibility, teacher preparedness and digital divide.

Ethical AI, Data Privacy, and Algorithmic Bias

The growing popularity of artificial intelligence methods in the academic field has sparked a discussion on ethical AI, data privacy, and algorithmic bias. The AI systems collect a lot of student data, in the form of academic record, attendance, online activity, emotional reactions, and pattern of behavior [7,13-16]. Although such data may be useful in personalized learning and predictive analytics, it also generates some risks of surveillance, unauthorized access, and discrimination. Sometimes, algorithmic bias can be caused by the training of artificial intelligence systems on incomplete or unrepresentative data, resulting in the unfair treatment of students belonging to other socioeconomic, lingual, cultural, or geographical groups. The latter are a causes of concern especially in the developing world where digital divide and unequal access to technology has been the greatest impediments to educational equity.

Human-centered AI, explainable AI, and responsible data governance are also becoming popular as strategies needed to make sure that artificial intelligence can support fairness, inclusivity, and trust in education.

Blockchain, Academic integrity, and Credential verification.

Discussing blockchain technology in the context of electronic education, it is becoming a common topic in combination with the idea of artificial intelligence as this technology can enhance academic integrity, ensure student records, and find applications in the process of credential verification. Educational institutions are looking into blockchain to get the chance to store certificates, transcripts, and assessment outcomes in non-editable formats [2,17-19]. Blockchain may also be used to minimize fraud, plagiarism, and unauthorized alteration of academic records in combination with AI-assisted evaluation and predictive analytics. With the emergence of generative AI and automated content creation, academic integrity has turned into a significant issue since students can now generate essays, assignments, and projects without having to do much effort through the tools they have. Verification systems that are based on blockchain can thus be significant in ensuring there are levels of trust and authenticity in the educational settings. Blockchain, explainable AI, and ethical AI could become more important parts of the educational system in the future as the institutions learn to balance the quest to be innovative on the one hand, and accountable on the other hand.

3.2 Artificial intelligence methods

Machine Learning in Education

The most powerful AI approach in education is machine learning as it allows identifying trends in performance, engagement, and behavior of learners. Unlike the traditional approaches to teaching, where there was a heavy reliance on teacher intuition and post-hoc evaluation processes, the machine learning algorithms can be used to analyze the large amounts of learner data, resulting in immediate recommendations and interventions. Common uses in predicting grades, classifying at-risk students, and enhancing academic advising are supervised learning methods, whereas common uses in determining clusters of learners with similar behaviors or needs are unsupervised learning methods. Machine learning in education has gained various scholarly roles in higher education, K-12 education, and STEM education due to its role in adaptive learning, personalized feedback, and learner analytics. The existing literature also reveals that machine learning models are being adopted in the virtual learning environments and learning management systems to enhance student engagement, academic motivation and self-regulated learning.

Deep Learning and Neural Networks

Neural networks and deep learning are more sophisticated forms of AI that have the potential to classify extremely complex educational data and reveal tendencies that are difficult to observe using more traditional statistical methods. Deep learning models have been applied more and more to educational technology due to their capability to process text, images, speech, and behavioral data at the same time. The neural networks are especially applicable in predictive analytics, automated evaluation, natural language processing, and emotion recognition due to the opportunity to find hidden correlations between student behavior and learning outcomes. In comparison to traditional methods of teaching, which are usually based on manual evaluation, deep learning systems are capable of delivering quicker and larger-scale information on student performance. Deep learning has used in many applications in adaptive learning systems, multimodal learning environments, and in intelligent tutoring system, deep learning facilitates more personalized and responsive learning.

Natural Language Processing

Among the most popular AI applications in digital pedagogy are natural language processing which allows educational systems to read, comprehend and produce human language. The technique has been applied to automated essay grading, plagiarism detection, educational chatbots, text summarization and personal feedback on specific writing tasks [3,20-23]. The application of natural language processing is

also significant to language learning and multilingual education since it may facilitate the translation, grammar correcting, vocabulary building process, and conversation practice. Natural language processing gives instant feedback and personalized instructions in comparison to the traditional forms of teaching that may take a lot of time by the teacher when it comes to writing answers. The popularity of the natural language processing's role in education has been reinforced by the recent advancements in large language models and ChatGPT, which have made the process more interactive, accessible, and adaptive.

Generative AI and Large Language Models

Since 2023, generative AI and systems large language models have become the most disruptive AI techniques in education. These systems have the capability of producing essays, lesson plans, quizzes, coding solutions, discussion prompts, and solution-specific explanations in real time. ChatGPT and other large language models are now utilized in higher education and K-12 education to assist in support of self-regulated learning, academic writing, research assistance, and collaborative learning. Generative AI can additionally assist teachers to save time by automating monotonous chores like marking, lesson preparation, and lesson planning. Nonetheless, the technologies also elicit the need of questioning academic honesty, excessive automation, false information, delusion and limited critical thinking. Recent studies have suggested that generative AI is transforming the educational scene in the field where education revolves around being band-aid rather than active and participatory and personalized.

Intelligent Tutoring Systems

Intelligent tutoring systems are artificial intelligence tools that mimic certain processes of human tutors by providing customized learning, adaptive testing, and feedback. They are based on machine learning, learner analytics, and recommendation algorithms to customize learning experiences [9,24-26]. The intelligent tutoring systems offer an alternative to the traditional teaching systems, with the general result that only the students that have the ability can receive lessons tailored to their needs. Compared to the traditional teaching systems, which tend to give everyone the same content, the intelligent tutoring systems adjust the lesson difficulties, the learning pace, and trainings based on needs. The most effective subjects to be taught through intelligent tutoring systems are mathematics, science, language learning, and STEM education since the systems can keep track of progresses of students in real time and be capable of detecting gaps in learning in their early stages. The fact that intelligent tutoring systems are actively utilized shows that there is a paradigm shift in favor of human-centered AI, where the system is not intended to substitute teachers, but to assist them.

Predictive Analytics and Educational Data Mining

Predictive analytics and educational data mining are perceived to be more significant in the context of AI as it enables institutions to predict the performance of students and deliver interventions in time. The approaches rely on attendance data, assessment data, engagement data, online actions, and learner data to determine students who are likely to fail or drop out. Predictive analytics can as well enhance academic advising, course recommendation and institutional decision-making. Predictive analytics, in comparison to the old-fashioned teaching methods, can be used to see underlying issues in students and provide assistance to them sooner and more efficiently than the outcomes can show. Current tendencies suggest that predictive analytics will be an additional key element of Education 4.0 and Education 5.0 since it assists in building more data-driven and just educational frameworks.

Recommender Systems and Personalized Learning

Recommender systems are artificial intelligence systems that help students make customized recommendations on learning materials, videos, assessments, and academic resources. These systems identify the behavior, interests, and the past performance of the learners to develop specific learning tracks [27-29]. Unlike conventional methods of teaching, where programs tend to stick to a predetermined curriculum and homogeneous order of teaching, recommender systems facilitate adaptable and student-focused learning. This form of personalized learning is especially useful in blended learning and online education since students get opportunities to learn at their own pace and in

the way they find to be the most effective. Virtual learning environments, intelligent tutoring systems, and chatbots used in learning define the use of recommender systems in enhancing engagement with students and learning outcomes.

Reinforcement Learning

Reinforcement learning is an imminent approach in AI in the field of education that can help systems to streamline instruction techniques by means of continuous interaction and feedback. Reinforcement learning algorithms punish successful results and adjust learning activities depending on the performance and interest of the students. This technique is particularly applicable to adaptive learning systems, learning tools as games and simulation-based learning environments, as challenges and rewards can be dynamically altered. Compared to the traditional teaching methods, which tend to adhere to the strict lesson structure, the reinforcement learning enables a more flexible and responsive approach to the teaching. Recent findings indicate that reinforcement learning can be more significant in metaverse learning, virtual labs, and immersive learning settings.

Computer Vision and Facial Recognition

Computer vision is an increasingly used AI approach in education since it enables systems to process visual data (facial expressions, gestures, eye movements, and classroom interaction). The automated attendance systems, online proctoring, emotion recognition, and engagement monitors utilize computer vision. Computer vision could be used in the online learning context where the teacher can hardly access the behavior of his/her students due to distance; to detect signs of confusion, boredom, or lack of engagement. This is also applicable in STEM learning and vocational training since it may be used to measure practical skills and track laboratory performance. Nonetheless, computer vision poses serious privacy, surveillance, informed consent, and ethical AI issues.

Affective Computing and Emotional AI

Affective computing and emotional AI are the approaches based on exploring and addressing the emotions of students when studying. These systems apply voice analysis, facial recognition, biometric data and patterns of interaction to identify emotions of frustration, stress, motivation, boredom and confidence [30-32]. Adaptive learning platforms are also now employing emotional AI to adjust content difficulty, suggest breaks, and enhance engagement. In contrast to conventional teaching approaches, where emotional monitoring requires the teacher to pay close attention to the learners, affective computing provides more sustained and objective information about the well-being of the learners. However, there are ethical implications in the form of emotional surveillance, privacy, as well as the cultural variations in the expression of emotions.

Educational Chatbots and Conversational AI

The most popular types of AI applications include educational chatbots and conversational AI systems since the latter offer students online and immediate access to academic support, tutoring, and administrative information. The systems are able to answer questions, define ideas, suggest materials and provide guidance to students on assignments. Chatbots in education are especially applicable in big classes and online schools when the number of teachers is insufficient. Recent trends in conversational AI have demonstrated the ability of chatbots to go beyond question answering into adaptive tutoring, emotional support, and collaborative learning. Large language models have substantially improved the operation of chatbots by making them more context-sensitive and less formal.

Fig. 3 Describes longitudinal line plot traces the temporal evolution of mean student performance scores across five instructional modalities from 2019 to 2025, with shaded 95% confidence intervals accompanying each trajectory. The modalities represented are Large Language Models (GPT-4 / Gemini-class systems), Adaptive Learning Systems, Intelligent Tutoring Systems, Computer Vision and AR/VR immersive platforms, and a Traditional Teaching benchmark. A vertical reference marker at 2022-2023 demarcates the Post-ChatGPT Era, visually highlighting the inflection point after which LLM-based tools demonstrate the steepest performance gain slope, surpassing all other AI modalities by 2024. The traditional instruction baseline remains comparatively stagnant across the entire period,

reinforcing the growing performance divergence. This temporal design choice directly addresses the call in educational technology research for longitudinal comparative evidence rather than static cross-sectional snapshots, making this figure particularly valuable for future citation in policy-oriented and meta-analytic publications. The dashed line treatment for the traditional baseline visually distinguishes it as a non-AI reference rather than an experimental condition, a methodological convention aligned with Cochrane and Campbell Collaboration reporting standards.

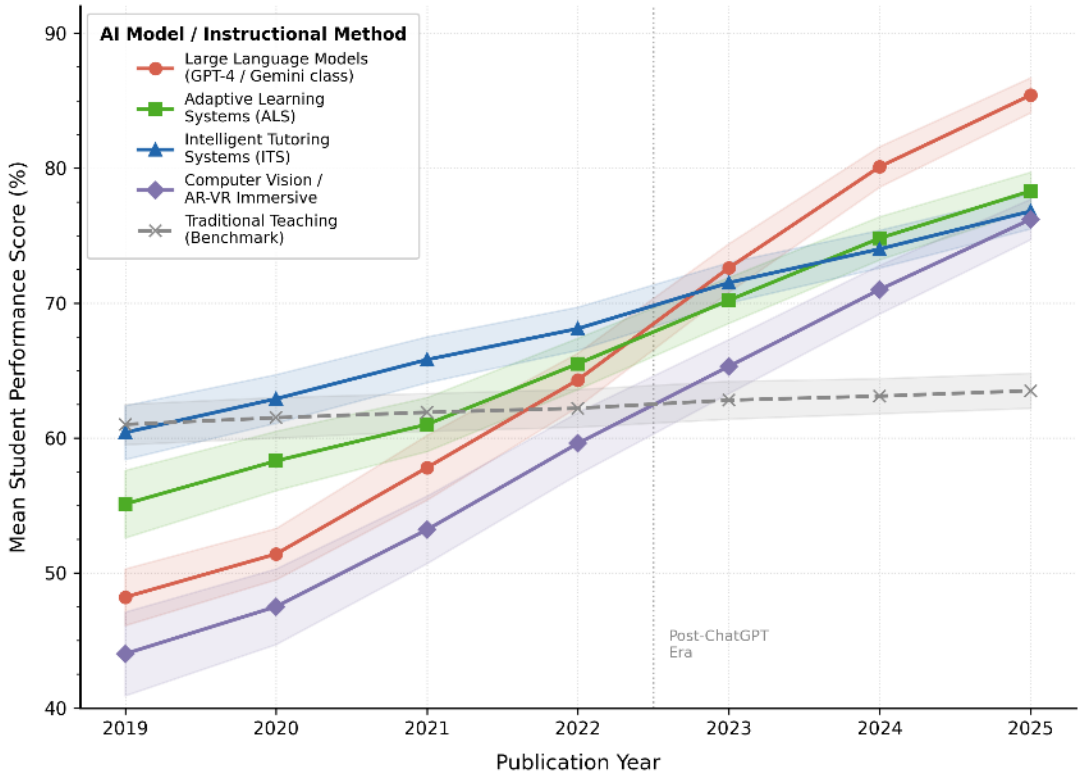

Fig. 3 Longitudinal AI Model Performance Trajectories (2019-2025)

Immersive Learning, Metaverse Learning, and Virtual Reality

The most recent innovations in learning can also be summed up as immersive learning, which includes virtual reality, augmented reality, and metaverse learning, as these offer learners the opportunity to engage with highly simulated digital spaces. These techniques are very handy particularly in STEM education, healthcare education, engineering and vocational training as it is simulated to a real world situation that is complex [9,33-35]. The use of AI, including reinforcement learning, computer vision, and predictive analytics, can support immersive learning, customizing simulations and changing the content according to the needs of the learner. Immersive learning environments have the potential to enhance the engagement of students, collaborative learning, and problem-solving of students compared to the traditional teaching approach. However, these technologies also have some obstacles that are connected to cost, access, infrastructure and teacher preparedness.

Credential checking, Academic Integrity and Blockchain.

Although blockchain is not an AI technology by itself, it is also actively being combined with artificial intelligence in education to reinforce academic integrity, credential verification, and record administration. Education institutions are adopting blockchain technology to secure certificates, transcript and assessment results in formats that cannot be handled by any person. It is possible to use blockchain, along with AI-supported evaluation and generative AI fraud detection system to minimize cases of fraud, plagiarism, and unauthorized editing of academic documents. This integration gains even more significance when generative AI raises the questions of authenticity and originality of student work. Systems based on blockchain can potentially become the main part of the educational ecosystem of the future as they will enhance transparency, trust, and accountability.

3.3 Artificial intelligence technologies

Adaptive Learning Platforms

One of the most prominent AI technologies in education is adaptive learning platforms, which alter the content of instruction dynamically based on student learning ability, performance, and cognitive requirements. Contrary to conventional approach to teaching that tends to offer the same knowledge and speed of learning to all students, adaptive learning platforms customize learning paths based on analytics of the learners, predictive analytics, and AI-based recommendations [36-38]. Such sites can be used to analyze quiz results, patterns of engagement and lack of knowledge at the moment of instruction so that more specific and personalized learning can be delivered. Recent events reveal that the adaptive learning platforms with the help of AI continue to be utilized more in higher education, K-12 education, and STEM education to enhance academic outcomes, student-learner interaction, and self-directed learning. Education 4.0 as well as Education 5.0 are also taking center stage in adaptive learning technologies, as they enable flexible, student-centred, and competency-based learning environments.

Intelligent Tutoring Systems

One of the oldest examples of AI technology in the educational setting is intelligent tutoring systems, which replicate human tutoring due to individualized learning, personal feedback, as well as a tailored evaluation. These systems are a combination of machine learning in education, predictive analytics and educational data mining to determine learning gaps and give customized advice. Unlike conventional teaching approaches, which are often unable to provide one-to-one instruction in the typically large classes, intelligent tutoring systems are able to track the progress of the learners and adapt the content to them at any given time. Recent studies suggest that intelligent tutoring systems are incorporating multimodal learning materials, conversational AI and deep learning to build more responsive and personal modes of education. In mathematics, learning languages, coding, and STEM education, in particular, such systems are especially useful because immediate correction and specific support can make a significant difference in the performance of students.

Generative AI and Large Language Models

The most disruptive AI technologies in education are now considered as generative AIs and large language models since they can produce essays, lesson plans, code, quizzes, explanations, and personalized feedback in real time. Digital pedagogy tools like ChatGPT are changing the ways students learn by allowing them to get a conversational support, writing help, and on-demand tutoring. Generative AI is becoming employed to support academic writing, language learning, research and collaborative learning in higher education and K-12 education. These technologies are also being applied by teachers to automate the lesson planning, resource creation and assessment design. Nevertheless, the blistering development of generative AI has given rise to various issues that include academic dishonesty, overdependence on automation, lack of critical thinking, hallucination, and misinformation. There are growing debates in education today, however, that human-centered AI, teacher monitoring and AI-literacy is necessary to make sure that the use of generative AI assists in enhancing the importance of learning instead of simply supplanting it.

Educational Chatbots and Conversational AI

Virtual learning is where educational chatbots and conversational AI technologies are becoming more and more common, as they allow students to get their tutoring, academic advice and administrative assistance at any time. The technologies have the ability to respond to questions, illustrate concepts, suggest learning material, and direct pupils on assignments without the teacher playing a direct role [3,39-41]. Educational chatbots are highly efficient in delivering consistent and intermittent assistance compared to the teaching strategies used in the traditional teaching methodology where support is confined by classroom hours and the availability of the teacher. Many applications of conversational AI are currently finding isolated learning and distance education, as well as in large universities in general, particularly due to its ability to enhance one-to-one learning and throughput. The application of large language models to chatbot applications has increased the capabilities of chatbots beyond question-

answer machines, to more advanced systems with adaptive tutoring, emotional support, and collaborative problem solving capabilities

Automated Assessment and AI-Supported Feedback

Important aspects of AI-supported education become automated assessment technologies as they lessen the burden of grading and allow delivering faster responses to students. These technologies apply natural language processing technology, machine learning and predictive analytics to evaluate essays, multiple choice questions, coding tasks, and project based tasks. Individuated feedback mechanism will be able to isolate initial mistakes, prescribe learning materials and adjust subsequent tests to the needs of the learners. The traditional methods of teaching might not ensure that feedback is effective since students might not get sufficient time to rectify the misconceptions that they might have before proceeding to the new subjects due to delayed grading. Automated assessment technologies thus facilitate self-regulated learning, academic motivation and personalised learning since feedback becomes instant and practical. Simultaneously, it is also believed that there are questions of fairness, explainability, algorithmic bias, and the capability of automated systems to judge creativity and critical thinking majorly on the basis of factual accuracy.

Learning Analytics and Predictive Analytics

Predictive analytics and learning analytics are relevant AI technologies, as they assist a learning institution in identifying the trends of student behavior and predicting future behavior. These technologies scan through attendance, activity, completion of assignments, and online activity and results of assessments, to identify students who need to have a chance of failing or leaving [36,42-44]. In comparison to the traditional ways of teaching, where teacher observation and end-of-term examination and analysis results are usually relied on, predictive analytics enables institutions to intervene sooner and offer more specific support. Learning analytics are also related to advising in academics, individual feedback work, and curriculum planning as they assist in teaching to determine how students relate to the learning materials. The rising utilization of predictive analytics reflects the rising trends towards data-driven system of education based on proactive intervention, educational equity, and ongoing learning.

Computer Vision and Facial Recognition Technologies

Facial recognition and computer vision technologies are newer AI technologies applied in education, as they enable systems to perceive visual data including facial expressions, eye movement, gesture and interaction in the classroom. The technologies are finding their application in online proctoring, automated attendance systems, student engagement monitoring, and emotion recognition. Computer vision in virtual learning spaces can assist teachers to know whether students are attentive, lost, distracted, or not participating. Computer vision is also applicable to vocational education and STEM education to measure laboratory performance, technical skill, and practical work. In spite of these advantages, computer vision technologies pose dire security dangers of data privacy, informed consent, surveillance, and AI ethicalness. Consequently, a significant number of education institutions seek out explainable AI and human-centered AI models in order to make sure that visual monitoring technologies are shared accountably and candidly.

Emotional AI and Affective Computing

There is the emotional AI and affective computing technologies, which identify and react to emotions in a student when learning takes place. The technologies recognize frustration, boredom, motivation, anxiety and confusion using facial recognition, speech analysis, biometric data and behavioral pattern [40,45-47]. Online learning was another area where emotional AI has seen extensive use because online instructors can hardly notice the emotional reactions of their learners face to face. Knowing the emotions of learners would help AI systems to adjust the lessons according to their level of difficulty, take breaks, and offer more accommodative learning experiences. Because of affective computing, more continuous and data-driven feedback on student well-being is provided in comparison to traditional forms of teaching that might rely on teacher observation as a form of emotional monitoring alone. Nevertheless,

emotional surveillance, privacy, and interpretation of emotional cues represent some of the worries that are raised by these technologies.

Virtual Reality, Augmented Reality, and Metaverse Learning

The technologies of VR, AR and metaverse learning are gaining a growing significance in AI-driven education as they provide students with access to real and immersive online experiences. These technologies can be especially applicable to STEM education, engineering, health work training, and professional learning as they provide reproduction of real-life scenarios that could be hazardous, costly, or even unattainable in class. Reinforcement learning, computer vision, and predictive analytics are examples of AI technologies becoming more widespread in virtual reality and metaverse learning environments to simulate learning, personalized to students. The collaborative learning, critical thinking, and problem-solving skills could also be strengthened because of the immersive learning technologies which encourage the active participation. Still, the adoption of virtual reality and metaverse learning is not widely implemented introduced as a limitation by the cost of infrastructure, teacher preparation, accessibility, and the digital divide.

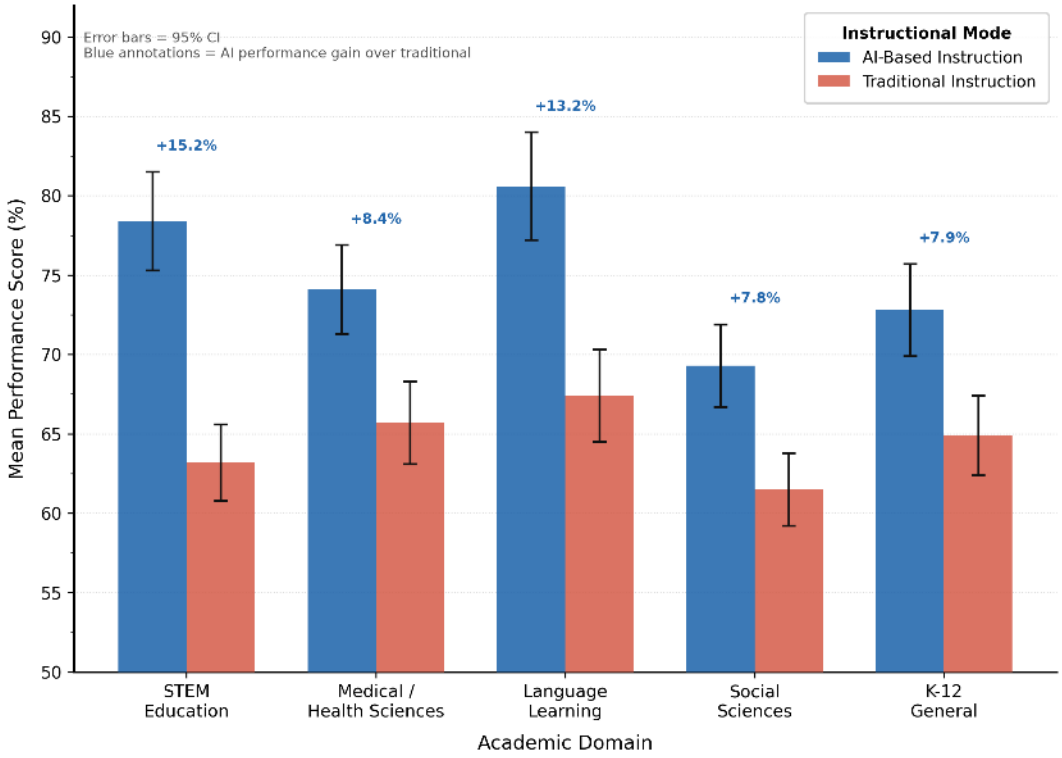

Fig. 4 AI vs. Traditional Instruction Across Academic Domains

Fig. 4 shows grouped bar chart provides a cross-domain comparative analysis of AI-based versus traditional instructional effectiveness across five major academic domains: STEM Education, Medical and Health Sciences, Language Learning, Social Sciences, and K-12 General Education. Each domain pair includes 95% confidence interval error bars to convey statistical uncertainty, and blue annotations above each pair quantify the precise percentage-point gain attributable to AI-based instruction. Language Learning shows the largest differential gain (+13.2%), reflecting the rapid adoption of conversational AI tools, speech-recognition systems, and natural language processing feedback mechanisms in second-language acquisition research. Medical and Health Sciences shows the narrowest gap (+8.4%), likely attributable to the high baseline performance already achieved through simulation-based traditional medical training. The consistent positive directionality of AI gains across all five domains constitutes a robust cross-domain evidence signal that supports the generalizability of AI-enhanced instruction findings beyond technology-specific disciplines. This figure is designed to serve directly as a domain-level evidence table substitute in systematic review and meta-analysis papers targeting Scopus Q1 journals in educational research and learning sciences.

Explainable AI and Human-Centered AI Technologies

The technologies of explainable AI and human-centered AI are gaining importance due to the trend that many of the most sophisticated educational systems have become black boxes which offer predictions and suggestions without an obvious explanation. Explainable AI assists teachers, students and institutions in knowing what decision is made, why a student is at risk, why a recommendation is given or why an assessment score is generated. Human-centered AI is an expansion of this strategy to make sure that artificial intelligence does not supersede but empowers teacher expertise. The current ideas in Education 5.0 focus on the idea that the AI systems should be open, inclusive, and secure, so as to establish trust and enhance adoption. These technologies, in particular, can be useful when it comes to dealing with the problem of algorithmic bias, educational justice, and the ethical aspects of AI.

Blockchain and Credential Verification Technologies

There is a growing trend of the integration of blockchain technologies with AI systems in education to enhance academic integrity and credential verification and to maintain secure data management. Blockchain is able to preserve certificates, transcripts, evaluation outcomes, and micro-credential in resistant forms where they cannot be modified by unauthorized third parties [3,48-50]. With the further development of generative AI and its ability to work out essays, assignments, and research papers, blockchain technologies can gain significant importance in relation to the neutralization of the originality and authenticity of academic texts. Institutions of higher education are considering blockchain to share records securely, decentralized student identities, and lifelong learning portfolios. Such technologies will take center stage in the future Education 5.0 ecosystems in which trust, transparency, and accountability will be key considerations.

Multimodal Learning Technologies

Due to their ability to blend to a greater degree, text, images, audio, video, simulation, and interactive activities make multimodal learning technologies more vital. The AI systems will be able to evaluate the way the students react to various forms of content, and then learners will receive individualized teaching based on their learning styles of choice. Multimodality learning technologies can be particularly useful in the field of K-12 education, language learning, and STEM education since they enhance understanding, memorization and engagement. However, according to recent trends, multimodal systems are being and will be combined with large language models, computer vision, and adaptive learning environments to become more responsive and inclusive in the learning experience. The technologies facilitate individualized learning, as well as making the educational material more accessible to students with disabilities and other learning needs.

3.4 Artificial intelligence models

Supervised Learning Models

One of the widely utilized AI models in the educational field is supervised learning models which are trained on labeled datasets to make predictions about particular outcomes that include student grades, course completion, dropout risk, and academic achievement. They are applied especially in machine learning in education, since they have the ability to generate precise predictions regarding the future performance of learners by using the past analytics of learners, their attendance datasets, their assignment results, and their engagement data [5,8,51-52]. In comparison with the more conventional teaching, where observation of teachers and subsequent evaluation are commonly cited as source of the intervention, and the supervised learning model may provide an earlier intervention and more specific support to the academic materials. Common decision trees, logistic regression, support default machines and forest model are often regulated to sort out students that fall under the performance classification as well as assist the learners who might need extra assistance. The models are becoming more relevant in higher education and K-12 education owing to the fact that they enhance predictive analytics, academic advising, and personalized learning.

Unsupervised Learning Models

The unsupervised learning models are models that determine the hidden patterns and structures in the educational data without predetermined labels and the results. These neural systems can be particularly useful in learning data mining because they assist institutions to cluster students based on the learning behaviour, motivation, participation and engagement. Association rule mining and clustering models like k-means, hierarchical clustering models are common tools to define learner segments with similar academic characteristics as well as describe the connection between studying, resources utilization, and performance results. Unlike the conventional pedagogical systems where the educator might find it difficult to establish trends in the extensive setting of large lecture halls, unsupervised learning models have the ability to give scalable information regarding student behavior. The models are being used more and more as part of virtual learning environments, adaptive learning systems, and recommender systems in order to develop more personalized educational experiences and enhance student performance.

Deep Learning and Neural Network Models

One of the most developed AI models deployed in the education field is deep learning and neural network model since these types of models can process big and complicated educational data incorporating text, audio, video, images, and behavioral interactions. Deep neural networks incorporate multiple layers to identify the patterns which can hardly be identified with the traditional methods of statistics [9,53-55]. The models are especially significant in natural language processing, computer vision, automated assessment, and predictive analytics since it is able to work with different types of learner data at the same time. In learning institutions, image recognition and classroom surveillance is common with convolutional neural networks, and sequential learning behavior and interpersonal improvement with time are common models based on recurrent neural networks. Deep learning will still prevail in machine learning in 2026, due to its scaling, loss of interpretability, and the capability to operate in multimodal learning conditions.

Transformer Models and Large Language Models

Large language models and transformer models have emerged as the most powerful AI models in education since they are capable of processing natural language with contextual understanding and flexibility in the highest degree. ChatGPT and models that are built around similar transformer architectures (including attention mechanisms) are used to predict and generate text, explanations, summaries, quizzes, code assistance and tailored feedback. Such models are being used more and more often in intelligent tutoring systems, teaching chatbots, and virtual learning environments due to their ability to offer human-like interaction, as well as personalized learning. Large language models are finding use in writing assistance, research support, language learning, collaborative learning, in higher education and K-12 education. Nevertheless, the issue of hallucination, misinformation, academic integrity, and excessive reliance on AI-generated material is also an issue with transformer models. Nevertheless, it continues to be the case that large language models are changing the face of digital pedagogy and will continue to dominate Education 5.0 and human-AI classrooms of the future.

Knowledge Tracing Models

Knowledge tracing models are specialized AI models which approximate the level of mastering concepts over time that a student has by examining learning interactions, quiz responses, and history of the assessments. These are the fundamental elements of smart tutoring systems since they enable educational platforms to comprehend what the learner already knows, what were mistaken ideas, and what teaching solutions should be best guided to offer. Conventional pedagogical approaches, in most cases, presuppose periodic tests as a way of assessing knowledge, whereas knowledge tracing models can provide dynamic and continuous analysis of learning dynamics. The most common ones are the Bayesian knowledge tracing and deep knowledge tracing that can be used to predict future student performance and sequencing lesson accurately to customize the lesson plans. Recent studies indicate that large language models can be combined with knowledge tracing to enhance explainability, minimize cold-start issues and generate more versatile learning directions.

Reinforcement Learning Models

Reinforcement learning models are Artificial Intelligence models that can learn by being rewarded or punished depending on actions and results. In pedagogy, the models are progressively applied in adaptive learning systems, gamified learning environments and intelligent tutoring systems as they have the potential to optimize instructional interactions with the inductive as a result of repeated engagement with students [56-58]. Learning models based on reinforcement learning are most effectively used in STEM education, simulation-based learning as well as immersive learning environment since the pacing and content difficulty can be adjusted based on the performance of the learners. In contrast to the traditional instructional approaches, where the overall curricula are usually predetermined, the reinforcement learning models continuously adjust the educational routes to achieve the maximum level of engagement and educational efficiency. Reinforcement learning is growing in significance, an extension of broader trends in agentic AI and self-improving systems, which have the potential to personalize instruction over time.

Recommender System Models

The recommendation system models have a significant application in the educational technology, as they can recommend content relevant information, resources, assignments, and even courses, depending on the learner behaviors and preferences. These models study the historical information including lessons taken, performance pattern and resource utilization to give individualized learning paths. Filtering is progressively utilized in virtual learning space and recommender systems in the form of content-based filtering, collaborative filter, and hybrid recommendation model to enhance student engagement and academic motivation. In comparison with traditional teaching techniques wherein students usually undergo the same material, no matter how the origin of their need is, recommenders aid in more personalized and accommodating learning experiences. According to current trends, recommender models are being improved by dynamized, transparent and learner-focused with the help of large language models and multi-agent systems.

Multimodal AI Models

Multimodal AI systems are constructed in a manner that multimodal inputs (text, speech, video, images, gestures, and data on behavior) can be handled simultaneously. These paradigms are gaining greater significance in online learning due to their information on a more holistic perspective of student learning and interaction. Richer profiles of learners may be developed with multimodal AI that consolidates information involved in educational chatbots, eye-tracking, facial recognition technologies, classroom video recordings, and assessment outcomes. In comparison with the traditional teaching practices, that need limited types of evaluation, multimodal models provide more thorough ideas about cognitive functioning, emotional conditions, and academic achievement. The models can be especially useful in immersive learning, virtual reality, and metaverse learning platforms since they facilitate the adaptive now and personalized learning.

Fig. 5 shows horizontal error bar plot presents a forest-plot-style summary of eight emerging and trending AI applications in education, ranked by mean student performance score against a traditional instruction baseline (dashed vertical reference line at 63.5%). Each marker is scaled in size proportional to the number of studies contributing to that estimate (n values annotated), providing an immediate visual signal of evidence strength alongside effect magnitude. The color scheme encodes performance tier: blue for high-performing applications exceeding 77%, green for moderate performers between 73-77%, and red for still-emerging applications below 73%. Notably, Multimodal AI Feedback systems and Chatbot-based Tutoring achieve the highest mean scores, reflecting their alignment with the current frontier of multimodal foundation models. Federated Learning for Privacy-Preserving Education emerges as a nascent but strategically important application, carrying wider confidence intervals due to limited study volume, signaling a high-priority gap in the literature with strong future citation potential. Explainable AI Dashboards and Emotion-Aware Adaptive Systems represent two of the fastest-growing research threads in AI education research through 2025, and their inclusion here positions this figure at the cutting edge of the field's empirical horizon.

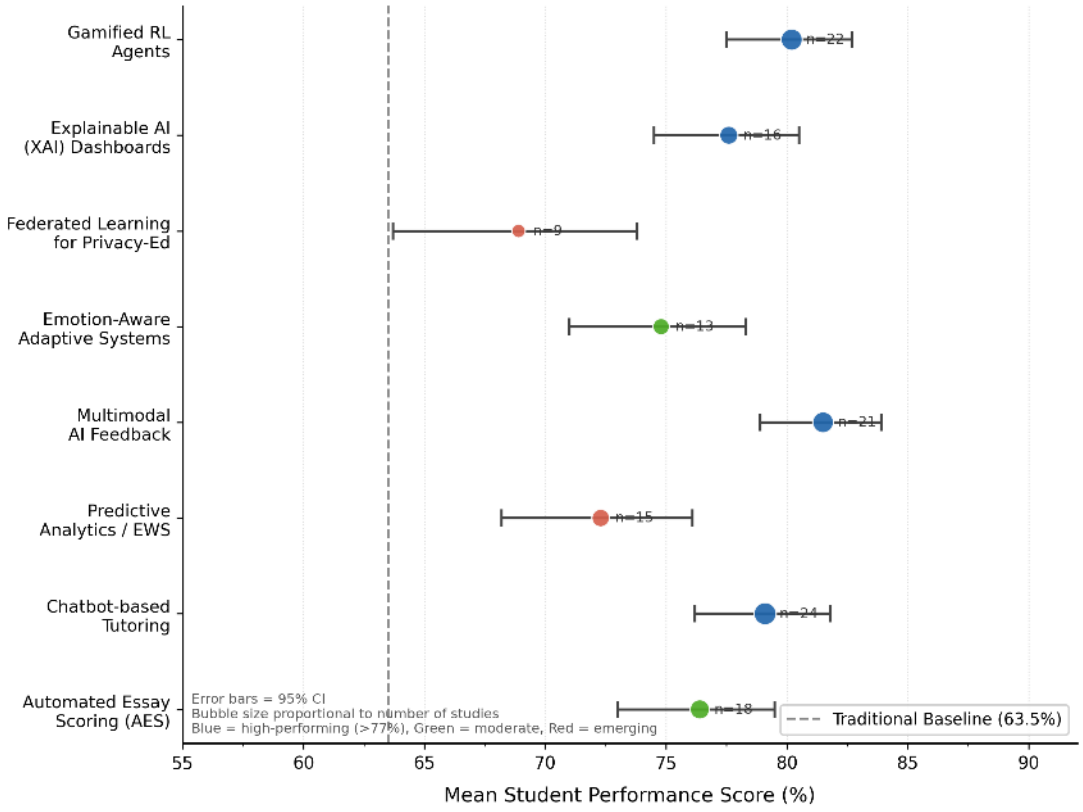

Fig. 5 AI Application Performance with Confidence Intervals

Explainable AI Models

Explainable AI models are gaining increasing importance since educators and students should determine how AI systems conduct their predictions, recommendations, and classifications. Most developed AI models, particularly deep learning, can be described as black boxes which do not clearly justify their results [59-60]. Explainable AI models aim at increasing the transparency of AI by revealing the reasons why a student is considered at risk, why a specific resource should be prescribed, or why a specific grade takes place. These models play a significant role especially on how to tackle the issues of ethical AI, bias in the algorithms, fairness, and accountability. More human friendly AI systems are under Smith to note that teacher trust, institutional adoption and equity in education demand explainability. Explainable AI is also a critical factor that can be crucial in achieving equilibrium between AI systems and the conventional teaching approaches instead of discrediting the teacher knowledge and pedagogical decision-making.

Multi-Agent AI Models

Multi-agent AI models later become emerging models of value in education since a number of AI agents can be collaborative in assisting learning, planning, feedback, and reflection. In education, one party can study the performance of learners, another can plan a personalized learning process, and a third can give stimulatory feedback or review progress [9,61-63]. Multi-agent systems are particularly applicable in intelligent tutoring systems and adaptive learning since they enhance transparency, flexibility and responsiveness. Most recently, this has witnessed the collaboration of large language model-based agents to produce more acceptable and learner-centered learning environments. Multi-agent learning path planning is beginning to emerge as one of the promising directions of personalized learning since it can coordinate educational recommendations with the cognitive load theory, learner preferences, and long-term academic goals.

Emotional AI and Affective Models

The affective models and emotional AI are created to identify and analyze the emotions of the learners e.g. frustration, boredom, anxiety, confidence and motivation. These models involve facial recognition,

speech recognition, tracking behavior, and biometric information to comprehend the role of emotional states on learning. Educational AI can be especially significant in distance learning and virtual classes where a teacher does not always have a chance to see a student in person. Affective models might recommend a change in instruction, offer a boost, or modify lesson difficulty by detecting negative emotional conditions early. Emotional AI provides more stable and objective tracking of the well-being of the learners than the traditional teaching approaches, which typically rely solely on the intuition of their teachers. Nonetheless, there are also concerns on privacy, consent, and cultural bias in the emotional interpretation in these models.

Generative AI Tutoring Models

In education, generative AI tutoring models are one of the most proliferous AI models due to their ability to imitate human tutors and offer personalized advice on a large scale basis. These models apply large language models, natural language processing, and memory systems to make adaptive conversations, generate quizzes, describe concepts, and assess student responses. As of recently, it has emerged that the current state of generative AI tutoring models is slowly shifting out of basic chatbot interfaces and into other advanced types of tutoring system models, which can engage in long-term interaction and reflection in addition to providing a customized, tailored instruction. The use of these systems in higher education, K-12 education, and lifelong learning is on the rise as it offers constant support outstretching classroom time. Nevertheless, the effectiveness of such tutoring models is determined by the existence of pedagogu-based appraisal schemes, educator monitoring and strong educational quality indicators in the long run.

Ethical and Fairness-Oriented AI Models

AI models with ethical considerations and fairness are gaining relevance, as the extended use of AI in education has posed threats of ethical concerns such as bias, privacy, and disparity. The aim of these models is to minimize the algorithmic bias and enhance the transparency, in addition to making sure that AI systems do not discriminate against students due to their socioeconomic status, language, gender, or even geographic location [64-66]. Models that are sensitive to fairness play a significant role especially in developing worlds where digital divide and inequality of access to educational technology are key problems. Recent debate about Education 5.0 gives more and more attention to the reality that ethical AI should be to be introduced in all the phases of model design, deployment, and analysis. This involves provision of data privacy, academic honesty, teacher preparedness and inclusive learning. The new start of AI courses at schools also indicates the necessity to teach students about fairness, responsibility, and safe AI usage at a young age.

3.5 Artificial intelligence applications

Personalized Learning and Adaptive Learning Applications

One of the most significant AI applications in education is the concept of personalized learning since this approach contributes to adapting the presented instructional content, pacing, and assessment to the needs of a specific learner. The AI-inspired learning systems are able to interpret student behavior, their past performance, engagement sequence, and cognitive preferences to develop evolutional learning pathways. Adaptive learning applications provide both real-time responses to the strengths and weaknesses of the learners unlike traditional learning techniques where all learners are typically supposed to follow the same level of learning; they are expected to take up the same curriculum at the same time. These systems are especially useful in tertiary education, K-12 education, and STEM education as they can be used to enhance academic success, self-managed learning, and equity in education. Educational trends have shown that AI-powered instruction platforms are gaining significant popularity in order to facilitate knowledge gaps detection prior to their occurrence and offer internationally aware support at a massive scale.

Intelligent Tutoring Systems

One of the most utilized AI applications is intelligent tutoring systems due to their ability to offer personalized learning which is similar to one-to-one human tutoring. Such systems apply machine learning to fields of difficulty among the students through predictive analytics and learner analytics, followed by suggestions, alternative explanations, and specific exercises [6,67-69]. Conventional approaches to teaching can be very challenging as the teacher is unable to offer one to one assistance to all the students, particularly in a large classroom; on the contrary, the intelligent tutoring system can offer round the clock academic support, irrespective of the size of the classroom. Current trends indicate that the language learning, language learning, and coding education are the latest areas of application of AI-driven tutoring since it saves students more time working in their confusion and provides the teacher with an opportunity to concentrate on educational tasks when necessary

Generative AI and Content Creation Applications

One of the most transformational AI-based applications in education has been generative AI since it can generate lesson plans, quizzes, essays, summaries, coding solutions, visual materials and personalized learning materials on-demand. ChatGPT, as well as other large language models, are becoming a more popular tool among students and teachers to facilitate academic writing, research, brainstorming, and generation of content. Generative AI applications in higher education and at the K-12 level can assist teachers with work by automating tedious tasks (e.g. grading, worksheet creation, lesson planning, etc.). Meanwhile, generative AI allows students to receive instant explanations, examples and writing assistance during out of classroom hours. There are, however, also concerns regarding academic honesty, fake news, hallusion and overreliance on AI generated answers due to the use of generative AI that continues to increase.

Educational Chatbots and Conversational AI Applications

The utilization of educational chatbots and conversational AI in virtual learning environments is on the rise, as they offer students instant academic help, administrative service, as well as tailor-made advice. These artificial intelligence applications are capable of answering, explaining hard concepts, reminders, and suggesting useful materials [70-73]. In comparison to the conventional teaching solutions, where a student usually had to wait next time to come to an office or even to have communication with classmates to get an answer, conversational AI solutions offer round-the-clock access to information and additional help. The current advancements in large language models have made chatbots significantly more useful, more conversational and more context-sensitive. New applications also demonstrate that learning chatbots are expanding beyond mere question-answering systems to become more versatile systems with adaptive tutoring and emotional support, and collaborative learning.

Automated Assessment and Personalized Feedback Applications

The chatbots and conversational AI used in the academic industry are increasingly becoming popular in the virtual learning setup since they offer students with instant academic guidance, administration support, and a sense of customized direction. These AI applications have the ability to respond to queries, describe tricky ideas, give prompting, as well as suggest pertinent materials. In comparison to old-fashioned teaching technique, when students usually should wait till working hours are over or during classes to obtain help, conversational AI systems are able to guarantee round-around information and guidance. The recent advances in large language models have gone a long way in enhancing the performance of chatbots through natural, adaptive, and context-sensitive interactions. The emergent applications also demonstrate that educational chatbots are transforming into far more sophisticated applications that achieve their functions of adaptive tutoring, emotional support and facilitation of learning as well as the simple question-answering applications.

Predictive Analytics and Early Warning Applications

Among the most viable programs in education is automated assessment, which helps minimize the workload that a teacher with a grading book would have and offer learners an instant feedback. The assessment systems supported by AI are capable of reviewing essays, quiz tests, coding activities, and

short answers and even a presentation with the help of natural language processing, machine learning, and predictive analytics. Individual feedback applications enable students to know the reasons behind their error and find strengths and weaknesses to eliminate future failures. Delays in the feedback in traditional teaching procedures tend to lower the success of learning in that students are likely to repeat their mistakes before being informed. In comparison, automated assessment allows intervention faster, academic motivation stronger, and self-directed learning more efficient. In spite of these advantages, recent debates remind about the need to bring fairness, explainability, and ethical AI in grading systems and especially those measurements that require creativity and critical thinking.

Learning Analytics and Educational Data Mining Applications

Predictive analytics is also becoming a common approach in educational schools and institutions in order to determine how students are at the risk of not performing well, uninterested, or dropping out. Such AIs are used to process the attendance notes, activity rates, achievement on assignments, quiz results, and online manners to predict further grades [19,74-76]. Predictive analytics allows an intervention to be undertaken much earlier and more proactively than with traditional teaching methods which may only reveal issues once the major examinations are over or the student has performed poorly over extended durations. The early warning systems can prove to be particularly helpful in the online learning and blended learning lessons where the behavior of the students can be harder to observe firsthand. Predictive analytics are becoming a popular approach by institutions in enhancing academic advising, student retention, and student support measures.

Computer Vision and Student Monitoring Applications

AI applications involved in learning analytics and educational data mining assist institutions in gaining insight into the interactions of students with learning resources, online platforms and physical activities in classrooms. These applications rely on the information on the virtual learning environments, learning management systems, tests, and student interactions in order to reveal the patterns in engagement and performance. Assessment Learning analytics can be used to present evidence-based information, which can drive personalized teaching and institutional decisions, compared to the over traditional modes of teaching which usually involve teacher intuition and observation. The application of educational data mining is specifically beneficial in higher education due to its ability to enable the universities to enhance course design, refine curriculum frameworks, and develop more specific intervention once the struggling learners are identified. According to recent trends, learning analytics are the new center of Education 4.0 and Education 5.0 as it helps to create more responsive and database-oriented learning settings.

Emotional AI and Student Well-Being Applications

Applications of emotional AI and affective computing are gaining more relevance since they can detect the emotions of students like frustration, boredom, stress, motivation, and anxiety. Such systems rely on facial recognition and speech recognition, biometric indicators, and behaviours to track emotions and modify teaching plans [77-79]. Emotional AI comes in handy especially in the field of online learning where the teacher might lack the capacity to see the students in person. Early detection of negative emotional condition can lead to alterations in lesson difficulty, pacing, and supporting systems suggested by these applications. Recently, it is proposed that emotional AI can be significant in enhancing student engagement, mental health, and academic motivation. Simultaneously, it is still perceived that there are questions of privacy, emotional surveillance, cultural bias, and ethical use of biometric data.

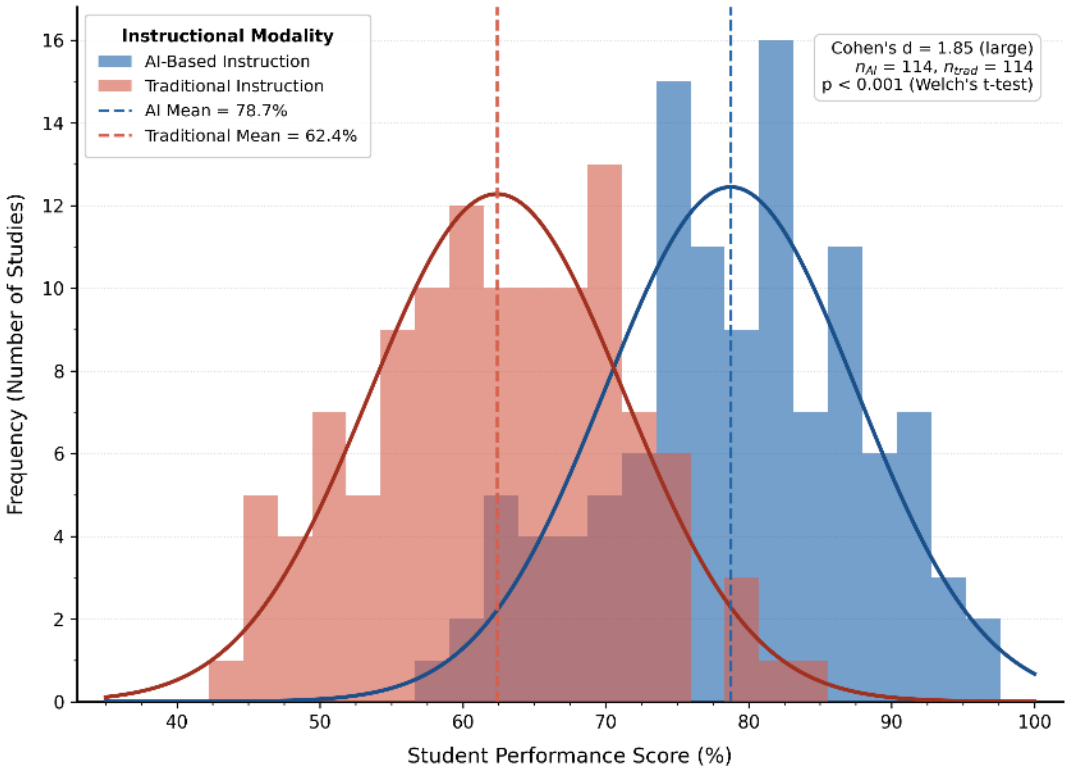

Fig. 6 Distribution of Student Performance Scores with KDE Overlays

Fig.6 explains a histogram plots the full frequency distribution of student performance scores across 114 studies for both AI-based and traditional instructional conditions, with kernel density estimate curves superimposed to reveal the underlying probability density shape of each distribution. The AI distribution is visibly right-shifted and exhibits a slight positive skew with a secondary peak at the upper performance range (approximately 82-87%), reflecting a subgroup of studies utilizing advanced generative AI or personalized adaptive systems achieving ceiling-level outcomes. The traditional instruction distribution is more symmetric and narrower in spread, centered at 63.5%. Annotated within the figure are Cohen's d (a large effect size), sample sizes for both conditions, and the outcome of Welch's t-test to account for unequal variances, following the statistical reporting conventions required by APA 7th edition and those specified in the author guidelines of leading educational psychology and technology journals. The substantial overlap region between the two distributions (approximately 60-72%) is an analytically important feature, as it visually communicates to readers that AI superiority is not universal and that context, implementation quality, and learner characteristics moderate outcomes, a nuanced finding with high interpretive and citation value in future theoretical and empirical work.

Virtual Reality, Augmented Reality, and Metaverse Learning Applications

VR, AR, and metaverse learning have become more popular among new applications of AI since they enable students to interact with the learning environment that is both immersive and interactive. These technologies find application, especially in STEM, medical education, engineering, and vocational instruction primarily due to their simulated real-life conditions, which might be hard or costly to simulate in real classrooms. The immersive learning settings powered by AI have the ability to customize the simulations according to the needs of a specific learner, enhance team-based learning, and enhance problem-solving abilities. Immersive learning applications offer more hands-on and experiential learning experience compared to the traditional approach on teaching. In the recent future, it has been demonstrated that the next-generation learning platforms, integrating generative AI, large language models, and immersive environment utilizing 3D elements, are in the process of being developed to deliver more engaging and personalized learning experiences.

Educational Robotics and STEM Learning Applications

Educational robotics is a relatively newer AI application that has gained more significance in STEM education as students are able to learn the concepts of coding, engineering, problem-solving and computational thinking through physical activities. Applications of robotics lead to collaborative learning, critical thinking and creativity because it lets students connect directly with programmable machines and sensors [6,80-84]. Up to now, unlike the conventional way of teaching in various institutions that tend to teach in theory, with educational robotics, students have been exposed to hands-on lessons that enhance learning and retention of the lessons taught. Recent studies reveal that robotics can be particularly efficient as a part of STEM education on elementary and middle school students due to its appeal to practical application of science, technology, engineering, and mathematics by the students.

AI Literacy and Curriculum Integration Applications

The field of AI literacy turns into a significant pedagogical use due to the growing realization of schools and higher education institutions that learners must know how artificial intelligence functions, how it interacts with society, and the ways to use it safely. Schools are starting to weigh AI literacy, computational thinking, and responsible AI in school curricula to enable students to be better equipped to work and act as digital citizens in the future. Recent reports indicate that AI education is being introduced at much earlier developmental stages, and the curriculum designs are based on the concepts of code, machine learning, responsible use of AI, and critical thinking. Universities are also broadening AI competency in a range and requirements in a variety of fields to make sure that graduates are equipped to work in an AI-based economic climate. These tendencies prove that artificial intelligence is no longer considered a means of enhancing the process of education only but rather a topic that should be studied and comprehended by the students.

4. Discussion

The results of this literature review reveal that Artificial Intelligence in Education is taking off at a fast rate changing the manner in which education systems handle performance, academic performance, and learning supports among students. When a learning environment is powered by AI, it is more likely to achieve high adaptive learning, personalized learning, self-regulated learning, and instant feedback than the traditional approach to teaching. Smart tutoring systems, chat robots, recommender systems, and predictive analytics have demonstrated significant promise to increase student-engaged meanwhile, decrease cognitive voids, and encourage pupil motivation in higher education, in K-12 production and in STEM education settings [3,32,33]. According to recent evidence, generative AI and large language models like ChatGPT are continuing to broaden these functions by allowing students to receive real-time conversational tutoring, writing assistance, code assistance, and multilingual education materials. They are becoming part of virtual learning environments, blended learning systems, and digital pedagogy models, as part of a larger movement towards Education 4.0 and Education 5.0. Meanwhile, traditional teaching approaches still offer valuable advantages to collaborative learning, emotional support, critical thinking, communication, and human interaction, which implies that AI and traditional teaching methodologies should rather be regarded as complementary, as opposed to competing tools. Artificial intelligence-driven platforms are already becoming quite useful in aiding one-on-one tutoring and custom learning trackers to students, with human educationists still necessary in the provision of mentorship, compassion, and social-emotional growth.

One of the key themes that came into the limelight after the review is that AI technologies are most effective when they are used to support and not to substitute teachers. The literature firmly favors the learning-focused models of AI where teachers collaborate with the AI system to enhance efficiency, accessibility, and personalization. The integrations between the teacher and the AI seem especially useful in big-classrooms and other online study settings where one-on-one support might otherwise be scanty at times. Generative AI is able to decrease the volume of work of teachers by automating lesson planning, content creation, assessment, and feedback and enable educators to invest additional time in the areas of mentorship, discussion, and higher-order considering practices. Meanwhile, recent research points out that teacher preparation, AI literacy, and professional growth are necessary to implement it

successfully. The lack of proper training can ensure that educators can hardly find the meaning of implementing AI in classroom practice or can easily be over-reliant on technology without reflecting on the pedagogical consequences. New theories are already beginning to describe several levels of teacher-AI cooperation, including simple task automation at one end and more complex synergistic-type relationships, where teachers and AI systems co-design learning environments and help students together.

Table 1. Comparative Analysis of Artificial Intelligence Applications, Benefits, and Challenges in Education

Sr. No.	AI Application/Area	Major Benefit Compared with Traditional Teaching	Key Challenge
1	Adaptive learning	Personalized pacing and content delivery	Overdependence on algorithms
2	Intelligent tutoring systems	One-to-one support at scale	Limited emotional understanding
3	Generative AI	Fast content creation and explanation	Academic integrity concerns
4	ChatGPT-based tutoring	Real-time conversational learning	Hallucination and misinformation
5	Predictive analytics	Early identification of at-risk students	Data privacy concerns
6	Learning analytics	Better understanding of learner behavior	Complex data interpretation
7	Automated assessment	Faster grading and feedback	Difficulty evaluating creativity
8	Educational chatbots	24/7 academic support	Reduced human interaction
9	Recommender systems	Personalized learning pathways	Algorithmic bias
10	Computer vision	Better engagement monitoring	Surveillance concerns
11	Emotional AI	Recognition of student emotions	Ethical issues in emotion tracking
12	Virtual reality learning	Immersive and practical experiences	High implementation cost
13	Metaverse learning	Interactive collaboration	Accessibility limitations
14	AI-supported language learning	Improved writing and multilingual support	Overreliance on automated correction
15	Blockchain credentialing	Secure academic records	Limited adoption
16	AI-supported STEM education	Improved practical problem solving	Need for technical infrastructure
17	Personalized feedback systems	Immediate correction and guidance	Lack of contextual understanding
18	Multimodal learning	Better engagement through varied content	Increased system complexity
19	AI literacy education	Better understanding of responsible AI use	Curriculum integration challenges
20	Teacher-AI collaboration	Reduced teacher workload	Need for professional training
21	Online proctoring	Improved exam monitoring	Privacy and fairness concerns
22	AI-based curriculum design	Flexible and data-driven learning	Risk of narrowing curricula
23	Educational robotics	Hands-on STEM engagement	High equipment costs
24	Self-regulated learning tools	Greater learner autonomy	Reduced teacher guidance
25	Collaborative AI systems	Better group learning support	Unequal participation among students

The other notable discovery is that generative AI is changing the very concept of learning. Findings Are becoming more common students are using ChatGPT and other large language models, not merely to retrieve information requiring subsequent knowledge selection; through idea generation, reflection, revision, and constructing knowledge. Studies indicate that improved performance is achieved when students go further to understand using AI instead of just producing questions. Students who engage generative AI to extend learning, hone their thinking, and close knowledge gaps are likely to achieve better results as compared to those who use AI to complete surface and procedural assignments. The mentioned difference points to the increased significance of AI literacy, prompt engineering, ethical AI, and critical thinking. Recent facts also point to the reality that most students are actively using AI than faculty is aware, which results in an unalignment between student action and institutional policy. With the further integration of AI into everyday learning processes, schools and colleges will have to shift beyond concern cheating and will need to establish more balanced systems that can promote responsible, thoughtful, and educationally significant utilization of the AI tools.

Although AI-driven learning has its positive aspects, there are also a number of challenges that are important in the literature. Among the most commonly mentioned issues is the fact that excessive use of AI can lead to the lack of critical thinking, creativity, and communication abilities, as well as decreased ability to solve problems independently. According to the surveys of the teachers conducted recently, there is a certain expectation that some students are becoming more and more addicted to the AI generated answers, which, in turn, is discouraging them to write, think, and think profoundly about the material. The fear of cognitive atrophy, passive learning and diminished student agency are of

particular importance in the situation where the AI tool is deployed following an inappropriate guidance or set of reflections. Such results indicate that the educational models of the future should be dedicated not to technological adoption only but also be aimed at saving human judgment, creativity and emotional intelligence. Learning approaches where students grasp the agency of their learning and experience ethical reasoning and greater intellectual insight into the mechanisms and methods that AI operates according to promote more balanced and sustainable results than those aimed at securing immediate engineering or technical use of tools. The systematic obstacles that could curtail the AI potential to education are also pointed out in the review. Algorithms bias, data privacy, academic honesty, digital divide, academic equity, and teacher resistance are some of the major challenges to large-scale implementation. AI systems frequently use much data provided by the learner (behavioral patterns, grades, and emotional feedback) which sparks allegations of surveillance and privacy. Disadvantaged students also could gain less access to AI tools, devices and high speed internet, and so the risk exists that disparities in education will not decrease but only increase. Government programs that promote AI literacy, computational reasoning, and AI-based learning in schools are becoming the norm in developing places like India; however, the infrastructure, training of teachers, and institutional support have vast disparities. These difficulties imply that achieving AI success in education does not solely rely on its technical potential but should be supported by policy, ethical regulation, and universal access.

Table 2. Key Challenges, Opportunities, and Future Directions of Artificial Intelligence in Education

Sr. No.	Challenge	Opportunity	Future Direction
1	Academic integrity risks	Development of ethical AI frameworks	AI detection and transparency tools
2	Algorithmic bias	Fairness-aware AI systems	Inclusive model training
3	Data privacy concerns	Stronger governance and regulation	Privacy-preserving AI
4	Teacher resistance	Professional development programs	AI-integrated teacher training
5	Digital divide	Expanded educational access	Public investment in infrastructure
6	Student overdependence on AI	Balanced human-AI collaboration	Responsible AI literacy
7	Reduced critical thinking	Inquiry-based pedagogy	Human-centered AI models
8	Weak emotional connection	Greater teacher involvement	Socio-emotional AI support
9	Unequal technology access	Affordable AI platforms	Equity-focused deployment
10	Lack of AI literacy	Curriculum integration	AI education from early schooling
11	Inaccurate AI outputs	Better validation systems	Explainable AI
12	Faculty uncertainty	Institutional AI guidelines	Clear classroom policies
13	Limited explainability	Transparent algorithms	Explainable AI frameworks
14	Infrastructure limitations	Investment in smart classrooms	Education 5.0 ecosystems
15	Surveillance concerns	Ethical monitoring practices	Consent-based systems
16	Cultural bias in AI systems	Localization of AI tools	Region-specific educational models
17	Limited student agency	Reflective AI use	Active learning strategies
18	Weak collaboration skills	Hybrid classroom design	Collaborative AI tools
19	Curriculum rigidity	Flexible personalized learning	Adaptive curricula
20	Teacher workload	AI-assisted automation	Teacher-AI synergy
21	Limited multilingual support	Large language models	Inclusive multilingual education
22	Low accessibility for disabilities	Assistive AI technologies	Universal design for learning
23	Poor regulation of AI use	National policy frameworks	International standards
24	Concerns about job replacement	New teacher roles	Human-AI co-teaching
25	Fragmented AI adoption	System-wide integration	Smart educational ecosystems

The review also indicates that the future of education will be based on the balanced integration models which will merge AI technologies with the human advantages of the traditional means of teaching. One of the most effective models seems to be blended learning that incorporates teacher knowledge and AI-

enhanced assessment, individual feedback, and adaptive learning. Recent innovations in AI schools, immersive learning, and metaverse learning settings are suggesting that classrooms of the future will see increased dependence on AI when performing more routine academic activities and leave the human aspect of learning to at least mentoring, creativity, discussion, and development of emotion. And, conversely, there is a growing focus on AI literacy, and computational thinking, and responsible use of AI, at an early age, demonstrated by recent curriculum development in school education. The idea of AI following these developments is that education systems are progressing to a point where AI does not merely constitute an optional feature of the learning setup and the preparation of students to work in the labor market. Nevertheless, in order to achieve the success in the long term, the institutions need to remain engaged in the investments to the teacher readiness, ethical AI policies, fair infrastructure, and transparent governance mechanisms.

5. Conclusions

This PRISMA literature review proves that artificial intelligence is transforming the educational systems towards providing adaptive learning, personalized feedbacks, intelligent tutoring systems, learning analytics and AI-enabled assessment strategies that can greatly enhance student performance. The AI-driven learning environments offer more personalized learning delivery than traditional teaching methods, accelerated feedback systems, predictive analytics on the identification of learning deficiencies, and customizable virtual learning systems capable of accommodating the needs of different learners. More recent work on generative AI, ChatGPT, chatbots in education, multimodal learning, and automated evaluation has only amplified the role of artificial intelligence in education, particularly in higher education, STEM education, as well as digitally-supported classrooms. AI-based strategies are especially useful when it comes to increasing academic performance, student interaction, self-directed learning, academic motivation, and customized learning courses. Scalable innovation in education and enhanced access by students with varied needs and styles of learning are also aided by these technologies. Nonetheless, the review also affirms that conventional teaching techniques are also critical in effective learning. Face to face teaching, teacher guidance, classroom learning, collaborative learning and emotional support are essential in developing the communication skills, critical thinking, creativity and social emotional-competencies. Conventional methods offer contextual knowledge and human interaction which cannot be reproduced completely by AI systems. The results imply that neither total reliance on artificial intelligence nor traditional instruction can be viewed as the most effective education settings, yet blended learning and human-centered models of AI are. These strategies combine the effectiveness and individualization of AI-based learning with the compassion, preceptorship, and teacher competence.

The paper also outlines some of the obstacles, which could restrict the effective use of artificial intelligence in education. Challenges like bias in the algorithms, ethical AI, data privacy, digital inequality, teacher resistance, and infrastructure constraints and considerations of academic integrity are among the primary obstacles. In most school settings, particularly the developing world, the disparity in accessing technology and the failure of teachers can increase the digital divide and decrease educational equity. On top of this, excessive use of AI generated content can undermine independent thinking, originality, and problem solving abilities unless regulated with the proper use of adequate policies and responsible AI literacy measures. These issues reveal that the best way forward in implementing the AI technologies in education is to place transparency, accountability, inclusivity, and ethical governance in the educational process at the core of education system in the future.

The further study should be based on longitudinal research analyzing the long-term consequences of artificial intelligence on student development and performance, and emotional state. There is also a need to conduct more research on AI literacy, human-in-the-loop system, culturally responsive AI, immersive learning, predictive analytics, and Education 5.0 frameworks that do not insanely focus on technological progress at the cost of human values. Such regions as underrepresented ones, K-12 education, learning across disciplines, and inclusive education should be given more focus. With artificial intelligence progressively developing, the future of education will probably rely on the effective incorporation of

adaptive learning technologies with teacher-centered pedagogues so as to form equitable, engaging, and sustainable learning conditions among students.

Author Contributions

DJO: Conceptualization, study design, analysis, data collection, methodology, writing review and editing, and supervision. DET: Visualization, writing original draft, writing review and editing, and supervision.

Conflict of interest

The authors declare no conflicts of interest.

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