

# A systematic review of generative artificial intelligence in education: Pedagogical impacts, ethical risks, and future directions

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## Abstract

The development of Generative Artificial Intelligence within learning institutions has presented both groundbreaking prospects and both serious issues on teaching quality, academic integrity, ethical responsibility, and student learning outcomes. Even though the use of Large Language Models, adaptive learning tools, intelligent tutoring systems, and assessment automation platforms continues to grow, it is still unclear how these tools can be used in pedagogy and whether they jeopardize ethical concerns and the future of education. The review has analyzed articles on Artificial Intelligence in Education, personalized learning, digital pedagogy, learning analytics, Human-AI Collaboration, and AI governance. The specific focus was made on the engagement of the students, reduction of the workload of the teachers, academic integrity, digital literacy, and data privacy issues. The results show that Generative Artificial Intelligence holds a great potential to enhance the personalized learning experience, automation of repetitive academic elements, aid in the design of assessments, improve content-generation, and create adaptable learning settings. Teachers are finding it easier to manage their administrations and access to teaching materials, and learners are receiving more personalized feedback and interactive learning opportunities. Nevertheless, the review also reveals significant risks connected with bias, misinformation, the opacities of the algorithms, plagiarism, unfair access, and the deterioration of critical thinking abilities. The paper concludes that the future adoption of Generative Artificial Intelligence in education requires a solid framework of AI ethics, explicit policies governing AI usage, enhanced digital literacy, and balanced Human-AI Collaboration designs that do not undermine the main role of educators in instruction.

Keywords: Artificial intelligence, Education, Adaptive learning, Personalized learning, Learning analytics, Data privacy.

## 1. Introduction

With blistering development of Generative Artificial Intelligence, the education sphere has changed dramatically with the introduction of the extremely sophisticated tools that can produce text, images, code, lesson plans, assessments, and individualized learning materials in real-time. Intelligent technologies are being used in schools, universities, and online education platforms at an accelerated pace due to the emergence of Large Language Models and multimodal AI systems [1,2]. Whereas the earlier educational automation systems mainly engaged in grading or administrative tasks, modern Generative Artificial Intelligence systems can now be used to provide complex teaching and learning capabilities, such as tutoring, curriculum design, feedback generation, language translation and student support. This development has made Artificial Intelligence in Education one of the most powerful spheres of education change, and universities are beginning to incorporate AI-based applications into both formal and informal learning systems. Generative Artificial Intelligence can be relevant to the field of education because it may be used to solve the long-standing issues of diversity in learning, the workload of teachers, student engagement, and unequal access to educational opportunities. AI systems

may be used to deliver individualized instructional content to a learner based on their needs, pace and preferences through applications like Personalized Learning, Adaptive Learning and Intelligent Tutoring Systems. These trends are especially significant in the area of higher education and online learning where the number of students in classes is rising and the administrative workload of teachers is growing. Generative Artificial Intelligence can reduce Teacher Workload, and at the same time, enhance learner outcomes and satisfaction through enabling instant feedback, automated content creation and data-driven decision-making. Moreover, Learning Analytics integration enables instructors to track the performance of students more efficiently and reveal at-risk students before academic challenges become complicated. In spite of these advantages, the extensive implementation of Generative Artificial Intelligence has put forward a number of serious issues concerning morality, regulation, and the standard of education. The influence of AI-generated content on Academic Integrity is among the most controversial topics since students are more likely to use AI tools to write their essays, complete assignments, write codes, and prepare for examinations. The consequences of such practices include issues of plagiarism, authenticity, over reliance on technology and loss of core critical thinking skills. Moreover, Data Privacy, surveillance, consent, and gathering of student data have become even more significant, as learning platforms are based on the bulk of information about learners to train and optimize AI systems. The Algorithmic Bias in AI-generated work is also dangerous to a significant extent, especially when it comes to disadvantaged marginalized learners whose biased recommendations, incorrect evaluation, or culturally insensitive content can be detrimental.

The present-day research environment demonstrates a swiftly expanding amount of literature which investigates the pedagogical uses and ethical issues of Generative Artificial Intelligence in educational settings. The current literature has covered the use of AI in digital learning, automated assessment, classroom engagement, bilingual learning, accessibility, and workgroups. The role of Human-AI Collaboration in improving the educational outcomes has also been explored by many scholars and it has been noted that AI systems are expected to provide support and not to replace human educators. Simultaneously, scholars have started talking about the relevance of AI Ethics, transparency, fairness, explainability, and accountability in AI-based educational systems. Nevertheless, a lot of the existing literature is disjointed with either being technological potentials or individual ethical issues without a cohesive view of the larger educational ramifications. A key research gap is thus present in the fact that no research has conducted thorough reviews, which can investigate the pedagogical effects, ethical threats, and future prospects of Generative Artificial Intelligence in a single context. The available research is constrained by a small disciplinary scope, short-term studies, or immobility by the different policy and governance problems. Another aspect that is not adequately discussed is the long-term effects of AI adoption on teacher identity, student autonomy, emotional well-being, digital literacy, and institutional governance. Specifically, insufficient focus has been placed on the fact that there is a need to have strong AI Governance systems that will be able to guarantee responsible AI implementation in various educational settings. With the rapid development of AI technologies, systematic reviews that will synthesize new evidence and define future research priorities with high citation rates are urgently required.

To address these shortcomings, this paper will conduct a systematic review of Generative Artificial Intelligence in education based on the PRISMA framework to analyse the current developments in the area. The purpose of the review is to examine the pedagogical value of AI-based educational tools, explore the ethical and social dangers of using them, and examine the future tendencies that may inform the Future of Education [3-5]. The paper combines evidence concerning digital pedagogy, personalized learning, academic integrity, AI ethics, responsible AI, and human-centered educational design to add to the overall picture in the question of how the implementation of Generative Artificial Intelligence can be both effective and responsible. It is hoped that the findings will assist educators, policymakers, researchers, and institutional leaders in coming up with balanced solutions that will allow AI to maximize its educational benefits and reduce its dangers.

## 2. Methodology

To guarantee the transparency, reproducibility, and rigor of the methodology used in the synthesis of available literature on the topic of generative artificial intelligence in the educational setting, the systematic review was carried out in strict compliance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines.

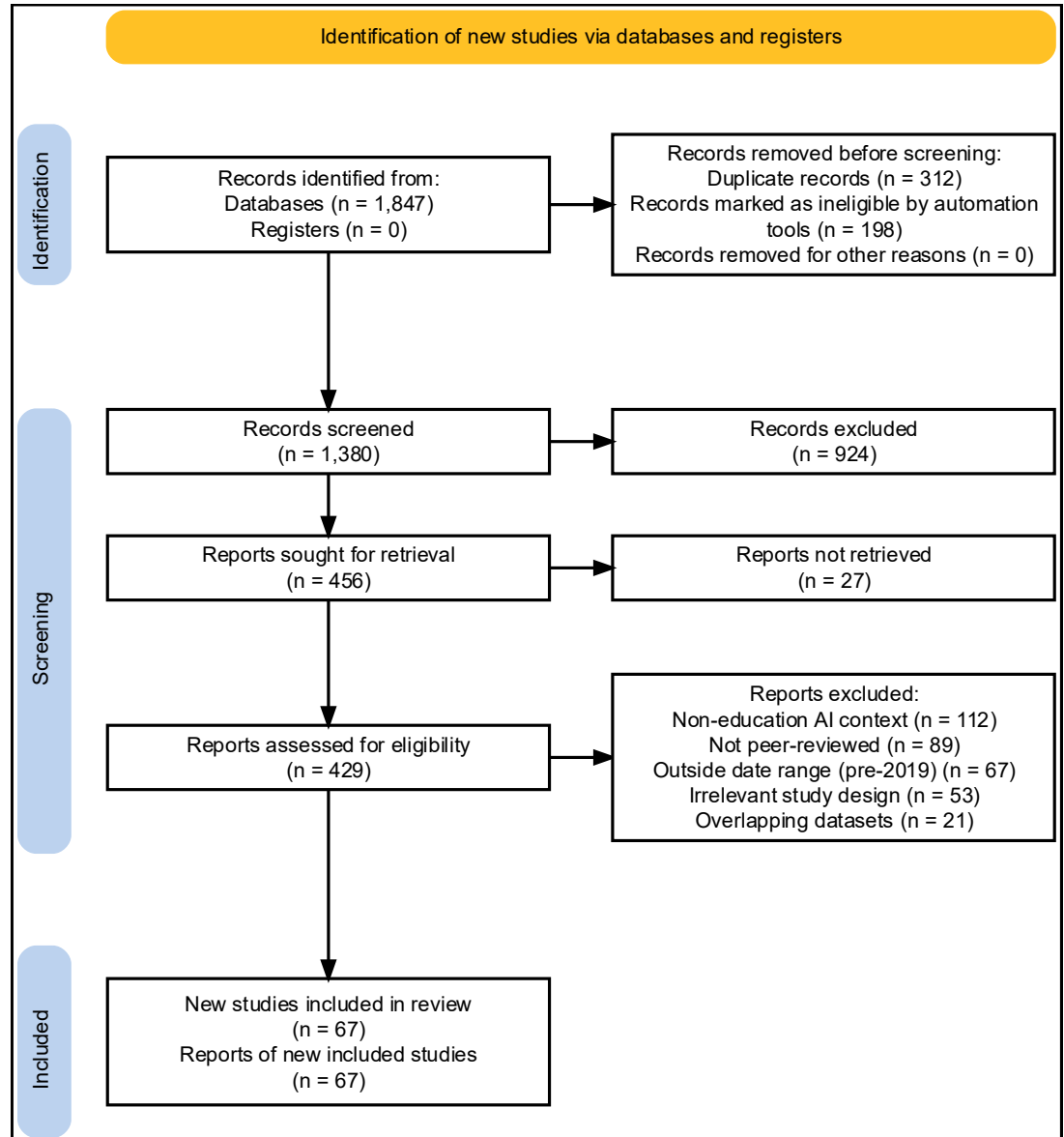


Fig.1 PRISMA Framework

The search of the database was conducted as a thorough and systematic search of four major academic repositories, namely Scopus, Web of Science, IEEE Xplore, and PubMed, to search publications published between January 2019 and December 2025, a timeframe selected intentionally to fulfill the objective of mapping the extent of proliferation of generative AI research just as the large language models and their use in education came into the The Boolean search strings employed across Scopus and Web of Science were constructed to maximize recall and precision, including: ("generative artificial intelligence" OR "generative AI" OR "large language model" OR "LLM" OR "ChatGPT" OR "GPT-4" OR "Bard" OR "Gemini") AND ("education" OR "learning" OR "teaching" OR "pedagogy" OR "higher education" OR "K-12" OR "classroom"); ("generative AI" OR "LLM") AND ("academic integrity" OR "plagiarism" OR "ethical risks" OR "AI ethics") AND ("education" OR "students"); and ("AI-assisted learning" OR "AI tutoring" OR "intelligent tutoring system") AND ("generative model" OR "transformer model") AND ("pedagogical" OR "learning outcomes" OR "student performance"). The

conceptual strings were translated into the IEEE Xplore and PubMed using their controlled vocabularies and MeSH where necessary. The inclusion criteria were that the studies had to be peer-reviewed empirical research, theoretical frameworks, or systematic reviews in English, specifically address generation AI tools in formal or informal educational contexts, and address at least one of the following dimensions: pedagogical effects, ethical risks, student or instructor experiences, or policy and future directions. These exclusion rules removed those records that were conference abstracts without access to the full-text, opinion pieces or editorials lacking empirical or analytical basis, those studies published earlier than 2019, and those studies that discussed AI in education in general without mentioning generative AI systems specifically. Following the PRISMA 2020 flow process, the initial database and supplementary citation searches yielded a combined total of 1,890 records (1,847 from databases and 43 from citation searching); after the removal of 312 duplicates and 198 automatically excluded records based on title-level irrelevance, 1,380 records proceeded to title and abstract screening, from which 924 were excluded for failure to meet inclusion criteria, leaving 456 reports sought for full-text retrieval, of which 27 could not be retrieved, resulting in 429 full-text articles assessed for eligibility; a further 342 were excluded based on five primary reasons — non-educational AI context (n=112), lack of peer review (n=89), outside date range (n=67), irrelevant study design (n=53), and overlapping datasets (n=21) — yielding a final corpus of 67 studies included in the qualitative synthesis of this systematic review.

### **3. Results and discussions**

#### *3.1 Artificial intelligence techniques*

##### Large Language Models in Education

Large Language Models are the most impactful group of Generative Artificial Intelligence technologies that influence education settings nowadays. The models are conditioned on large textual data, and operate on the transformer-based neural models to interpret, generate, summarize and evaluate words with a high level of fluency and contextual sensitivity. In education, Large Language Models are finding more applications in providing feedback on essays, planning lessons, generating questions, automated tutoring, facilitating discussions, and supporting multilinguals. Their capability of creating personalized learnings in real time has largely enhanced the scalability of individualized teachings particularly in online courses and classroom settings that are resourceful. These models are being embraced by educational institutions in order to accommodate learners with different needs in regard to learning such as those with language barriers, disabilities, or differing levels of performance in their learning activities. Another possibility of the increased popularity of Large Language Models in education is associated with the fact that this type of models can enhance the productivity of teachers and decrease the number of repetitive tasks. Teachers are able to create rubrics, summarize reading content, come up with quizzes, design activities and even offer formative assessment using these tools. Nevertheless, the application of such models also triggers issues of factual accuracy, hallucination, bias, overdependence and less critical thinking in the students. Consequently, the further research is more inclined to the equilibrium between the advantages of automation and the necessity of human control so that the Human-AI Collaboration is considered the key point of the educational process.

##### Transformer Models and Deep Learning Architectures

Most of the current applications of Generative Artificial Intelligence in education now use Transformer Models as the architecture. Transformer models, unlike the previous recurrent neural networks, have self-attention mechanisms that allow them to learn large volumes of information more efficiently and learn the relationship of contexts in longer text sequences [6,7]. This has enhanced the performance of learning systems like language translation, automated grading, text summary and conversational tutoring systems to a great extent. The popularity of the transformer model has boosted the creation of the advanced educational technologies that can facilitate the real-time and context-sensitive interactions among the students and intelligent systems. Transformer-based systems can be used in adaptive learning environments to understand the behavior of learners, detect misunderstandings and improve the

situation by giving specific recommendations. Their combination with speech recognition, natural language generation and multimodal interfaces are also increasing their educational utility. The future of transformer models in education is probably a smaller and domain-specific model that is more efficient and can be deployed safely in institutional infrastructures.

#### Natural Language Processing for Educational Content Generation

Generative Artificial Intelligence applications that are aimed at educational purposes rely on the premise of Natural Language Processing. AI systems are able to read queries provided by students, create explanations, analyze the quality of writing, sentiment detection, and conversational support with the help of Natural Language Processing techniques. The mentioned abilities are especially relevant to digital pedagogy where learners are becoming more dependent on AI-enriched systems to provide on-demand services and deliver interactive content. Natural Language Processing has been used in education in automated scoring of essays, detecting plagiarism, grammar correction, intelligent question answering, and summary of academic content. Multilingual education and inclusive learning environments are also greatly assisted by these technologies; this is particularly relevant to students whose level of proficiency in a language of instruction is limited. The current tendencies of Natural Language Processing are emotion-sensitive tutoring systems, real-time dialogue analysis, and context-sensitive feedback systems that have the potential to improve student engagement and motivation. In spite of these developments, there is still a worry about cultural bias, language inequality, and the accuracy of AI-generated explanations in more complex areas of the subject.

#### Machine Learning for Personalized Learning

Machine Learning plays the key role in the construction of individualized learning systems that focus on educative content based on the individual learner traits, performance, and preferences. Machine Learning algorithms process vast amounts of data about students, including the results of assessment tests, the history of interactions, attendance, and other such indicators, to establish custom learning paths [2,8-10]. These systems are becoming more popular to identify the at-risk students, prescribe resources, forecast academic performance, and customize instructional plans. Implementing the idea of Machine Learning as a part of Personalized Learning environment can decrease the educational inequalities by offering specific interventions to students with the need of special attention. Predictive analytics models are finding application in higher education to predict risks of dropping out, to improve curriculum design, and retention rates. In the future, the focus of the advancement of the field of Machine Learning may be put on transparency, fairness, and explainability to make sure that AI-based advice is comprehensible and just to the representatives of various groups of students.

#### Intelligent Tutoring Systems and Adaptive Learning

One of the oldest AI methods in the educational field is Intelligent Tutoring Systems. They are systems that replicate one-on-one tutoring, which gives the learners instant feedback, personalized instruction and the dynamic content depending on their progress. IT systems are commonly combined with rule-based algorithms, Machine Learning models and Natural Language Processing features to provide personalized learning experiences. The growing complexity of Adaptive Learning systems has facilitated the ability of educational systems to be more sensitive to the needs of the individual learners. Adaptive Learning technologies are able to change the level of difficulty, recommend additional learning resources, and detect the gaps in learning in real-time. These systems are also useful when used in STEM education, language learning, or professional training where learners have varying paces of learning. New studies are now looking at integrating Intelligent Tutoring Systems with emotional recognition and conversational AI as well as multimodal interfaces to create more natural and interactive learning experiences.

#### Learning Analytics and Predictive Modeling

Learning Analytics is a significant field of Artificial Intelligence in Education innovation. Learning Analytics is the process of collecting, analyzing, and interpreting learner data to enhance the outcomes of education and decision-making in an institution [1,11-12]. Predictive modelling is applied to detect

the behavioural patterns in the students, predict academic risks and suggest specific intervention. Learning Analytics combined with Generative Artificial Intelligence enables learning institutions to have a better understanding of student engagement, participation, and achievement. The integration of predictive analytics with the automated feedback systems will enable the educators to offer proactive assistance to the struggling learners before their performance deteriorates drastically. Nevertheless, the growing popularity of Learning Analytics also creates some concerns in terms of privacy of data, as well as surveillance and the ethical application of student data. Research on privacy-preserving analytics, federated data systems, and educational data governance ethics is expected to be carried out in the future.

#### Computer Vision in Educational Environments

Computer Vision is becoming a relevant aspect of Generative Artificial Intelligence in learning, especially in remote learning and assessment. Computer Vision technologies are able to scan through the facial expression, gesture, eye movements and classroom dynamics to track the student engagement and emotional conditions. These methods have found application in proctoring systems, attendance tracking, simulations in laboratories and in augmented reality learning environments. Computer Vision is finding more uses in the education sector and this has been achieved by using image recognition, handwriting analysis and generation of visual content. Computer Vision systems can be used in skill training in medical education, engineering and vocational training with visual demonstrations and simulation based feedback. Nevertheless, it has been observed that there are ethical issues associated with visual monitoring technologies such as surveillance, consent, bias, and student autonomy. Consequently, the future educational uses of Computer Vision will probably focus on the idea of transparency, participatory choice, and privacy-aware design.

#### Multimodal Learning and Generative AI

Multimodal Learning can be described as the combination of text, pictures, audio, video, and interactive media in one educational system. Generative Artificial Intelligence has greatly increased the opportunities of multimodal learning as it allows creating various and engaging learning content. Students are now able to communicate with AI systems which incorporate speech recognition, image analysis, textual descriptions and simulated environments to enable more in-depth learning experiences. The multimodal learning technologies are especially useful in science learning, language learning, design and professional training when the complex concepts are better explained using visual and auditory means. Multimodal learning is further becoming more significant in education due to the growing application of virtual reality, augmented reality, and digital twins. The next stage of development will be in the area of personalized multimodal experiences with customized content format based on the preferences of the learner, cognitive styles, and accessibility requirements.

Fig.2 is a scatter plot maps the relationship between model scale (measured in billions of parameters on a logarithmic x-axis) and educational task accuracy (%) across twenty representative generative AI models categorized into four groups: proprietary large language models (LLMs), open-source LLMs, multimodal models, and domain-specific models. Each category is encoded by a distinct color and marker shape to enable clear visual differentiation. Proprietary frontier models such as GPT-4o and Claude 3.5 Sonnet occupy the upper-right quadrant, demonstrating that extremely large parameter counts correlate with higher accuracy on educational benchmarks including reading comprehension, mathematical reasoning, and pedagogical question answering. A log-linear trend line fitted to proprietary LLMs illustrates a diminishing-returns pattern in performance scaling. Notably, domain-specific models such as Med-PaLM 2 achieve competitive accuracy despite modest parameter counts, suggesting that targeted fine-tuning on educational or scientific corpora can offset the advantages of raw scale. This visualization is particularly relevant for researchers designing cost-efficient AI deployment strategies in resource-constrained educational environments.

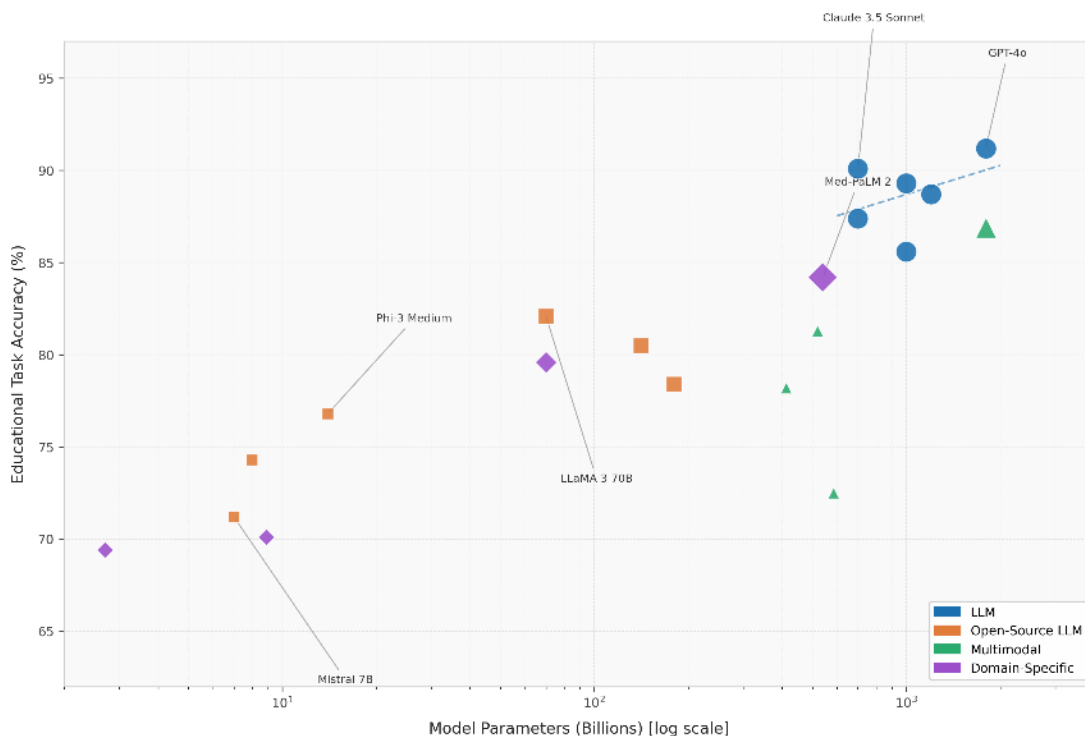


Fig.2 Scatter Plot: Generative AI Model Parameters vs. Educational Task Accuracy

### Reinforcement Learning for Educational Optimization

Reinforcement Learning is a method that is increasingly being sought as a way of optimizing learning routes and adaptive learning methods. The Reinforcement Learning systems are based on the interactions and feedbacks that allow them to determine the most effective teaching actions in the course of time [13-15]. These systems can be applied in the educational setting to prescribe exercises, order learning materials, and tailor the learning process to the performance and interaction of the students. Reinforcement Learning has been applied in education in a very promising way in areas of intelligent tutoring systems, game-based learning and adaptive assessments. Through continual adaptation of learning routes based on the student performance, the Reinforcement Learning systems will be able to optimize the retention and motivation of the learners. Nevertheless, the deployment of such systems has to have a substantial amount of training information and the problem of ethical concerns, in particular, when the results of automated decision-making affect academic advancement or grading.

### Generative Adversarial Networks and Diffusion Models

Generative Adversarial Networks and Diffusion Models are gaining more and more relevance in the creation of educational material. One of the ideas that can be taught via the use of Generative Adversarial Networks is generated realistic images, videos, and simulations that may be applied to multiple disciplines, including medicine, engineering, and environmental science. Recently, Diffusion Models have been in the limelight due to their capability of producing quality visual and multimedia images with greater stability and realness. The methods are especially applied in simulation based learning, virtual laboratory, and immersive learning. As an illustration, artificial intelligence generated anatomical models, architectural designs, and engineering prototypes can be used to enrich experiential learning and minimize the costs of the material. Nonetheless, misinformation, deepfakes, and authenticity are also problematic when it comes to the use of synthetic media. Consequently, schools are becoming in need of policies to draw the line between the lawful educational simulators and the fraudulent AI-made content.

## Knowledge Graphs and Semantic Educational Systems

Knowledge Graphs are also being applied to structure learning information and enhance intelligent search, recommendation and content generation systems. Knowledge Graphs are ideas and associations in structured forms, which allow AI systems to have an understanding of the ways of relating ideas across disciplines [16]. In learning institutions, they can be used in curriculum mapping, concept relating, identification of prerequisites and semantic search. Knowledge Graphs can be used with Generative Artificial Intelligence to produce more contextual and accurate responses on an educational platform. The explainability can as well be enhanced through these systems which demonstrate how certain recommendations or conclusions are made. Recent studies indicate that Knowledge Graphs are likely to be the core of future educational ecosystems because they will allow more open, interconnected and interdisciplinary learning experiences.

## Explainable AI, Federated Learning, and Ethical AI Systems

Explainable Artificial Intelligence is gaining more relevance in the teaching and learning field since teachers and learners should be aware of how AI systems arrive at their decisions. Explainable AI methods enhance trust, transparency, and accountability through giving a clear explanation of the recommendations, assessments, and predictions. This is especially crucial in education decisions that are stakes when it comes to admissions, grading and predictions of academic risks. Simultaneously, Federated Learning is becoming one of the promising methods of ensuring the safety of student data without depriving the institutions of the ability to enjoy the benefits of AI development through collaboration. Federated Learning enables models to be trained on multiple devices or institutions without using raw data and is more likely to reduce privacy risks and enhance compliance with data protection requirements. Such developments are closely associated with more general issues of AI Ethics, fairness, accountability, and transparency. With the rise in Generative AI usage in educational institutions, a growing awareness is emerging that new systems should be developed in an ethical way, privacy-conscious, and be consistent with the concepts of responsible innovation.

### *3.2 Artificial intelligence methods*

#### Machine Learning Methods in Educational Systems

Generative Artificial Intelligence in education is based on the methods of machine learning, as it is through this approach that systems are able to identify patterns, predict things, and modify educational content, depending on the interactions of students. The methods of supervised learning are often applied to categorize the learners by the level of performance, predict the risk of dropout, and distinguish the students who might need extra assistance [16,17]. Unmonitored learning procedures are used to group students according to their similar learning behaviours, patterns of engagement and achievement results in order to have more specific instructional interventions. The role of semi-supervised learning techniques is gaining more and more significance due to the fact that educational data usually have a limited amount of labeled data, in large organizations where data gathering is usually decentralized across several systems. The growing popularity of machine learning processes in the educational sector shows how predictive modelling can be used to improve institutional decision-making, individualize learning processes and enhance educational management systems. There is also need to enhance real-time educational decision-making that contributes to the growth of machine learning processes. The machine learning algorithms can be used to predict future academic performance highly based on past attendance, submission of assignments, quiz performance, and attendance records. These prediction systems have been highly incorporated into the digital learning space to enable the educators to intervene even before the students fail or get disengaged. Researchers are increasingly concerned with making educational systems more transparent in relation to machine learning, less biased, and predictive recommendations that are both fair and understandable by the educators and learners.

### Deep Learning and Neural Network Methods

Deep Learning algorithms have revolutionized the educational technology by making AI systems analyze intricate text, speech, image, and behavioral data patterns. Deep learning techniques are based on the multi-layer neural network structure which is able to learn the salient features of large datasets without requiring a lot of manual writing. Deep learning applications in the educational sphere are utilized to identify the emotions of students, analyze the engagement of the students using the facial expression, identify the patterns of handwriting, and assist the tutoring systems based on speech. The adaptive learning platforms have also begun to embrace deep learning techniques as they can represent very complicated relationships among student behavior and learning outcomes. CNNs and recurrent neural networks are popular in the field of education and are utilized in processing time-series data, classroom video streams, and history of student interactions. In more recent times, the deep learning techniques have been integrated with multimodal learning techniques to develop systems that can simultaneously study written responses, voice exchanges, and visual actions. These advancements suggest that deep learning systems will probably continue to form the heart of the education sector in the future, especially when educational institutions feel the need to learn more precise and scalable means of comprehending the requirements of the learners.

### Transformer Models and Attention-Based Methods

Transformer Models have emerged as the standard under the majority of modern Generative Artificial Intelligence applications due to their reliance on attention-based systems that enable the systems to be more efficient at processing long sequences of information than the previous neural architectures. Transformer techniques are particularly practicable in educational contexts since they are able to comprehend the context of long essays, student discussions and teaching content and can keep all the interactions coherent [12,18-20]. Attention-based systems are becoming increasingly common in automated essay marking, curriculum generation, tutoring systems and multilingual classrooms. Such techniques are able to determine the correlation between concepts, reveal misconceptions in student answers and offer a context-driven response. Transformer models are also especially significant in the educational context since it allows one to create conversational agents capable of answering the questions posed by students naturally and providing them with instructional explanations in real time. With the ongoing development of transformer methods, smaller and more dedicated models of education are likely to become more widespread, particularly when a secure and cost-effective deployment of AI is the desired goal of the institution.

### Large Language Model Methods for Educational Content Generation

The use of Large Language Models has emerged as one of the most relevant techniques in Artificial Intelligence in Education since they can be used to create essays, lesson plans, quizzes, explanations, and personalized feedback. The approaches are based on pretraining on a large scale and on the vast amount of texts, and then fine-tuning on specific educational tasks. students Large Language Models may help write, research, code, learn a language, and solve problems by conversational advice and instant reply. Large Language Model approaches are becoming more popular in educational institutions as ways to enhance the work of teachers and minimize the number of repetitive tasks. Such techniques are particularly useful when it comes to online learning since they operate in the long term and offer personalized assistance on a large scale. Nonetheless, one can also find that there are also serious issues associated with hallucination, misinformation, plagiarism, and over-dependence on AI-generated content. Subsequently, the further application of Large Language Models to education is likely to be centered on the development of more transparent, more domain-oriented, and ethically regulated systems that can work within the institutional frames.

### Natural Language Processing Methods in Education

Educational AI is largely based on Natural Language Processing techniques since they allow the systems to comprehend, create and analyze human language. Some of these Natural Language Processing approaches are sentiment, text, semantic and topic modeling, summarization, and named entity recognition. The applications of these techniques in the educational settings are highly common in

assisting automated grading of learners, plagiarism detection, production of feedback and conversational tutoring. The significance of Natural Language Processing techniques is also relevant in multilingual learning conditions since it can be used to translate educational resources, facilitate the process of learning the second language, and enhance the accessibility of students with a variety of linguistic backgrounds. The current trends in Natural Language Processing are more focused on contextual interpretation, emotional recognition, and support of the dialogue. Such techniques will become even more prominent in the further educational systems as educational institutions will use more individualistic and language-conscious teaching methods.

#### Transfer Learning and Fine-Tuning Methods

It is also possible to note that the approaches to transfer learning and fine-tuning are gaining relevance in the educational AI due to their ability to customize the existing models to the needs of particular academic areas, the needs of a specific group of students, and the needs of a particular institution. Transfer learning techniques minimize the necessity of having huge educational data, and makes use of previous models knowledge [21-23]. These models are then refined by means of fine-tuning to execute specialized tasks, e.g. grading mathematics assignments, producing scientific explanations, or aiding legal and medical education. Such techniques are especially useful in the education industry since the institutions are not always able to afford the resources needed to train large AI models initially. With the strategies of transfer learning and fine-tuning, schools and universities can transform AI systems according to the local curricula, cultural standards, and language preferences. The increased popularity of these approaches also contributes to the creation of the domain-specific educational AI systems which are more precise, topical, and cost-efficient.

#### Prompt Engineering and Retrieval-Augmented Generation Methods

The concept of Prompt Engineering has become one of the most significant ways of enhancing the quality and relevance of AI-generated educational content. Prompt engineering consists in instructing Generative Artificial Intelligence systems to make more accurate and structured answers and context-specific responses. Quizzes, lesson plans, explanations, summaries, and assessment rubrics are created in educational facilities as a result of prompt engineering techniques. The Retrieval-Augmented Generation techniques also enhance the performance of AI with the integration of language generation and systems of information retrieval. Instead of using internal model knowledge, retrieval augmented techniques use external databases, textbooks, institutional documents, and educational repositories to generate more credible results. Such techniques are becoming more popular in tutoring systems, academic research assistants, and curriculum design tools in that they assist in alleviating the hallucination and enhancing the accuracy of facts. The current trends will focus on adaptive prompt engineering approaches that will automatically personalize the content depending on the needs and learning situations of the students.

#### Reinforcement Learning Methods for Adaptive Educational Systems

The reinforcement Learning techniques are gaining currency in educational technology, as this allows systems to learn with the help of trial, feedback and reward systems. The reinforcement approaches to learning are particularly beneficial in the adaptive learning systems, in which AI is required to continuously adapt the educational material according to the performance of the students [24,25]. Such techniques are able to streamline the learning process, prescribe the appropriate exercises, and identify the best feedback techniques to use with the individual learners.

Fig. 3 describes multi-series line plot captures the temporal growth trajectory of six major generative AI application categories in education based on peer-reviewed publication counts from 2019 through 2025. The curves are smoothed using B-spline interpolation to highlight macro-level trends without obscuring year-specific data points marked by distinct markers per category. A shaded annotation band spanning 2023 to 2025 demarcates the post-ChatGPT era, emphasizing the dramatic inflection in research output following the public release of large language models in late 2022. AI-assisted content generation and academic integrity detection exhibit the steepest growth trajectories, reflecting heightened scholarly and institutional attention to generative capabilities and misuse risks respectively. Intelligent tutoring

systems and personalized learning paths demonstrate consistent, sustained growth throughout the entire period, indicating their established research maturity. Federated learning for education, while the lowest in absolute publication count, shows an accelerating upward trend from 2023 onward, signaling emerging momentum in privacy-preserving AI for distributed educational settings.

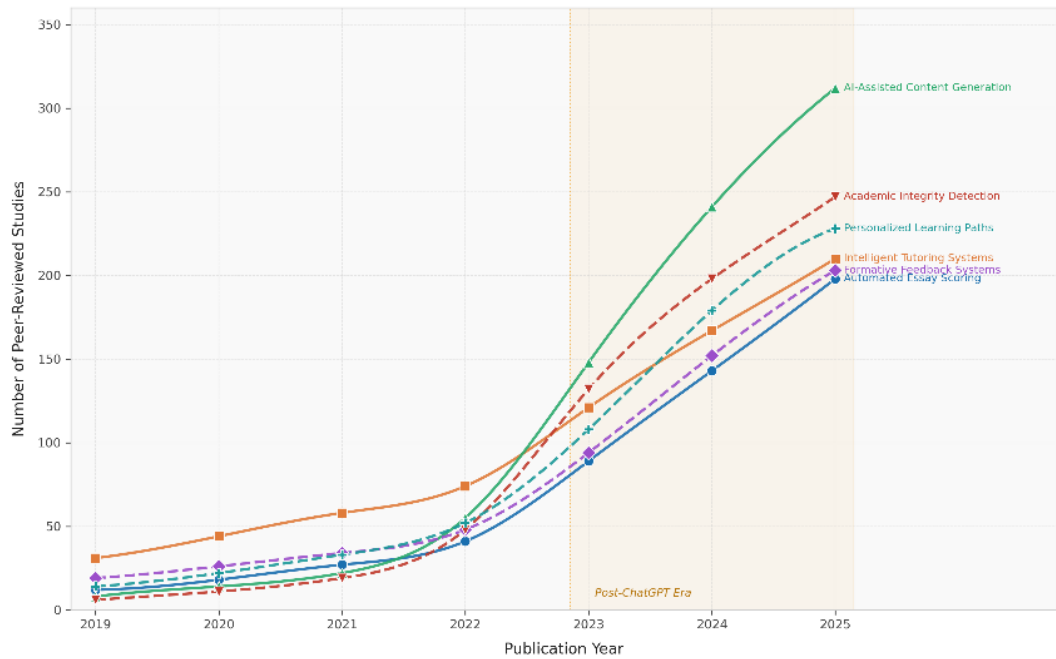


Fig.3 Line Plot: Longitudinal Adoption Trends of Generative AI Applications in Education (2019-2025)

Educational games, simulation based training, and intelligent tutoring systems are also popular applications of reinforcement learning techniques since they can be dynamically adjusted to the emerging learner behaviors. Reinforcement learning systems can also detect the instructional methods that result in the greatest student engagement and retention of knowledge by constantly evaluating the student progress. But, these strategies need to be monitored as well, since ill-scaffolded reward systems can unwillingly promote the behavior of superficial learning or support the status quo in education.

#### Intelligent Tutoring and Adaptive Learning Methods

One of the most developed and commonly used types of educational AI is the Intelligent Tutoring Systems and Adaptive Learning. The intelligent tutoring techniques give the students step by step instructions, instant feedback, and tailor made instruction that resembles a one-on-one teaching. The adaptive learning techniques employ the student performance data to modify the speed, the difficulty, and the format of instructional material. These techniques are especially useful in mathematics, science, learning a language and professional education as they are able to react swiftly to any misconceptions of learners and tailor the instruction to their needs. The methods of intelligent tutoring and adaptive learning are becoming more and more integrated with the emotional recognition, speech processing, and conversational AI technologies to make the learning experience more engaging. The future of these approaches will probably consist of very immersive systems incorporating adaptive feedback and augmented reality together with virtual reality and multimodal learning interfaces.

#### Learning Analytics and Predictive Modeling Methods

The Learning Analytics approaches are aimed at studying the students in order to enhance learning performance and organizational efficiency. Predictive modeling techniques are based on past and present educational data so as to predict student success, risk factors, and evidence-based decision-making [26-28]. Such approaches are getting more widespread in higher education as a predictor of dropout rates, a measure of engagement, and curriculum design. The processes of learning analytics can also assist teachers in determining the aspects that lead to academic success including attendance, participation, and study habits. Combining predictive analytics with Generative Artificial Intelligence

systems, learning institutions will be able to offer proactive interventions that enhance retention and minimize performance disparities. Nevertheless, such approaches also involve some concerns about the privacy of the data, consent, and ethical application of student information, particularly when predictive systems are applied to high-stakes academic outcomes.

#### Federated Learning and Privacy-Preserving Methods

Federated Learning approaches have become one of the critical solutions to the issue of educational data security and confidentiality. Federated learning enables AI systems to be trained on several devices or institutions without having to share raw data of students. This method is particularly relevant to education since schools and universities frequently work with the information that is sensitive and connected to the performance of students, their attendance, and their personal history. Data-sharing programs and cross-institutional approaches to the use of cloud-based AI systems are becoming more and more popular in educational institutions, which explains the need to implement privacy-saving practices. The federated learning techniques have the potential to enhance co-operation among the institutions and minimize the chances of data leakage and regulatory infractions. The future state of AI in education will depend on privacy preserving practices more due to heightened requirements of students, teachers, and policymakers to protect their personal information.

#### Explainable AI and Ethical Decision-Making Methods

The methods of explainable Artificial Intelligence are also gaining relevance since educators and students should learn how the AI systems generate recommendations, predictions, and decisions. Explainable AI techniques give interpretable results, which can be comprehended by the user to determine why some feedback, grades, or interventions will be produced [29-31]. This is especially necessary in academic situations that are of high stakes like admissions, scholarship distribution and prediction of academic risk. These approaches are directly related to the general issues of AI Ethics, Algorithmic Bias, and Data Privacy. The development of educational AI systems should be done in the manner that minimizes discrimination, enhances fairness, and ensures autonomy of learners. Explainable AI practices can be useful in helping the institutions to recognize any biases, monitor them by adhering to ethical practices, and build more confidence in the AI-based education systems. Since the role of AI is also growing, the concepts of explainability and ethical responsibility will become an inevitable part of Future of Education and the development of human-centered digital pedagogy in general.

### *3.3 Artificial intelligence technologies*

#### Large Language Models as Core Educational Technologies

The most significant technological advancement in the present day Generative Artificial Intelligence in education is the use of Large Language Models due to their capability to comprehend, create, summarize and personalize textual content at the scale. These technologies have become part of learning management systems, tutoring applications, assessment systems, and institutional knowledge systems to assist students and educators in real-time. Essay generation, question answering, curriculum design, language translation, coding support, and automated feedback are some of the growing uses of Large Language Models. Their worth is that they can produce very contextual responses and scale across the academic levels, subjects and needs of learners. Newer learning platforms are also becoming more based on next-generation Large Language Models that have better reasoning, multilingualism, and multimodality, enabling them to handle text, audio, images, and video disjointedly. The increasing maturity of these technologies is also contributing to the change in experimental tools in the classroom to institution-wide AI infrastructure integrated into the admissions, advising, assessment, accessibility, and workforce preparation systems.

Large Language Models are also revolutionizing the role of teachers and digital pedagogy due to their rapid growth. Teachers are also adopting such technologies to cut on administration, create teaching materials and enable personalized learning experiences. Nevertheless, recent reports also show the

increasing interest in the topic of excessive reliance on AI systems and the possible deterioration of the critical thinking among students. According to surveys that will be held in 2026, most of the teachers are of the view that students are becoming overly dependent on AI generated responses, which may diminish creativity, quality of writing and independent thinking. These issues support the necessity to position Large Language Models as facilitative educational technologies as opposed to human teaching substitutes.

#### Transformer Models and Foundation Model Technologies

Transformer Models are the technology underlying the majority of Generative Artificial Intelligence models applied in education. Transformer networks are based on attention models that allow AI to work with massive amounts of data, perceive long-term contextual interactions, and produce consistent results in long-term interactions [3,32,33]. This technology design has made a great contribution to the quality of automated tutoring, text summarization, lesson generation and multilingual learning applications. Transformer Models are also fast becoming foundation models, which can be used to support a variety of educational tasks via a single unified architecture. The emergence of foundation model technologies is noteworthy in that more and more educational institutions are in need of flexible systems, which can be used to accomplish various functions in various departments and by various users. One model can now facilitate the content generation, accessibility services, recommendation system, and student advising without having to use several independent tools. Recent trends in 2026 also emphasize the rise of smaller and more efficient transformer technologies that could be deployed on-premises, which means that schools and universities can run AI systems safely in their own networks and save on computation expenses and privacy concerns.

#### Multimodal Artificial Intelligence Technologies

Multimodal Artificial Intelligence is emerging as among the most radically disruptive technologies in education since it integrates text, image, audio, video, and sensor data into a single AI space. Multimodal technologies contrasted with the previous text-only systems enable learners to engage with learning platforms through speech, diagrams, handwritten notes, screen shots and videos. Such technologies find their application in science, engineering, medicine, and language learning, in particular, as they allow the students to study the concepts in a plurality of sensory modalities. The reason behind the increasing significance of multimodal technologies has been the general trend of more comprehensive and engaging educational experiences. Multimodal Large Language Models are now capable of interpreting laboratory diagrams, drawing analysis of student drawings, generating a narration of a description of a drawing, and interactive simulation. According to the recent studies, it has also been revealed that the recent educational studies have been largely associated with text-based AI whereas the full potential of multimodal technologies is still underutilized. This implies that multimodal systems will probably be among the most significant future directions of Artificial Intelligence in Education especially as educational establishments continue to focus on accessibility, inclusivity, and individualized learning.

#### Cloud Computing and Edge Computing Technologies.

Generative Artificial Intelligence technologies in the educational field can be deployed using Cloud Computing since most of the advanced models demand a considerable amount of processing power, data storage, and scalable infrastructure. Cloud-based educational artificial intelligence systems enable colleges to obtain large-scale language models, virtual learning assistants, predictive analytics systems, and multimedia content generation systems without necessarily buying costly local hardware [4,34-36]. This has greatly brought access to the Artificial Intelligence in Education especially to institutions that have less technical resources. Meanwhile, Edge Computing is becoming a significant complementary technology since it is an opportunity to have AI applications that process data much closer to the user than to fully rely on centralized cloud servers. The technologies of Edge Computing are highly appreciated in the educational settings where the concerns of privacy, latency, and offline availability play a significant role. To decrease reliance on the external servers and enhance data security, schools and universities are looking at edge-based tutoring solutions, local speech recognition technologies, and on-device evaluation technologies. The integration of Cloud Computing with Edge Computing will

most likely develop hybrid AI infrastructures that will be able to balance performance, scalability, and privacy protection.

#### Smart Learning Systems and Intelligent Tutoring.

The Intelligent Tutoring Systems are also among the oldest developed and used AI technologies in the field of education as they offer students personalized assistance, real-time feedback and adaptive teaching models. These systems are more and more fed by the Generative Artificial Intelligence technologies that are able to study the behavior of learners, detect their misconceptions and offer personalized advice to improve them. The Intelligent Tutoring Systems are popular in mathematics, learning languages, science training, and in professional training since they can dynamically respond to the needs of students. Adaptive Learning technologies go even further and modify the difficulty of content, the speed, and the format of instructions based on the student performance. Adaptive platforms in the modern models are based on behavioral data, assessment outcomes and engagement indicators to scale personalized learning experiences. New trends in education indicate that the technologies will be more valued as schools shift to competency-based learning, skill-based credentials, and more flexible learning opportunities in line with employability and lifelong learning.

#### Computer Vision and Image Processing Technologies

Computer Vision technologies find their way to the educational setting more and more, to analyze visual data and provide more interactive learning process. Computer Vision systems have the potential to track classroom activity, identify facial expressions, scan handwritten papers and assist automated proctoring of online exams [37-40]. Such technologies prove especially helpful in the case of remote learning when instructors have to learn novel methods of monitoring student engagement and attention. Other real world fields where computer vision technologies are being put into practice include the fields of medicine, engineering, and vocational training as it can be used to aid image-based assessment, simulation and demonstration. AI systems have the ability to interpret anatomical models, engineering models, and scientific observations in detail to give feedback. Such technologies are, however, associated with the issue of surveillance, consent, and privacy since they usually involve continuous image capturing and behavioral surveillance. Consequently, it can be predicted that in the future, Computer Vision can be used in education with a more emphasis on transparency, ethical governance, and student freedom.

#### Speech Recognition and Text-to-Speech Technologies

Text-to-Speech and Speech Recognition technologies gain more and more significance due to their contribution to the level of accessibility and the development of more natural relations between AI and students. Speech Recognition technologies enable the students to interact with the educational systems in terms of voice commands, spoken answers, and conversational dialogues. Younger learners, language learners and students with disabilities who can find interfaces based on traditional text to be challenging can find these technologies especially useful.

Fig.4 is a grouped bar chart presents composite pedagogical impact scores (on a 0 to 100 Likert-aggregate scale) for six prominent generative AI techniques assessed across four education levels: K-12, undergraduate, postgraduate, and professional training. The techniques represented are Retrieval-Augmented Generation (RAG)-based tutoring, fine-tuned LLMs, prompt engineering, multimodal generative AI, agentic AI systems, and federated learning. Each group of bars represents one technique, with four adjacent bars corresponding to education levels encoded by distinct colors. Agentic AI systems record the highest impact at postgraduate and professional training levels (83.4 and 85.1 respectively), reflecting their suitability for complex, self-directed inquiry tasks. Multimodal generative AI achieves the most balanced high performance across all levels, underscoring the pedagogical value of integrating text, image, and audio modalities for diverse learner populations. Federated learning consistently yields lower scores, particularly in K-12, where interpretability and deployment infrastructure remain barriers. Numerical annotations above each bar facilitate precise cross-condition comparison, a feature valued in meta-analytic and systematic review contexts.

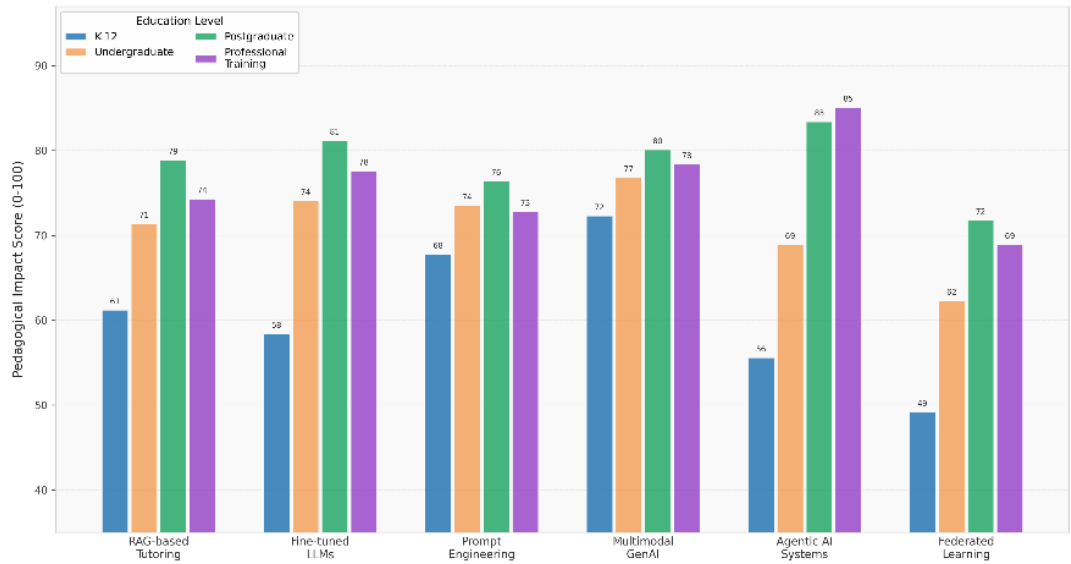


Fig.4 Grouped Bar Chart: Pedagogical Impact Scores of GenAI Techniques Across Education Levels

Text-to-Speech technologies, as well, aid in inclusive education, as it is possible to transform written resources into spoken audio to allow the visually impaired students and the learners with reading challenges to learn. Recent developments in generative audio systems have seen the creation of more realistic, expressive and context-aware synthetic voices, allowing educational systems to offer narrated lessons, spoken feedback, and interactive conversations. The growing popularity of voice-based learning technologies can be seen as a more general move toward more humanistic and accessible online education.

#### Extended Reality, Virtual Reality, and Augmented Reality Technologies

The technologies of Extended Reality are becoming popular due to the fact that they have the ability to provide an immersive learning experience, which takes advantage of Generative Artificial Intelligence and digital simulation. ER encompasses both Virtual Reality and Augmented Reality applications, allowing students to participate in the world of three-dimensional content, virtual laboratories, and interactive simulation [4,41,42]. Medical education, engineering, architecture, and vocational training are the most useful areas of use of these technologies, as they provide learners with an opportunity to train their skills in safe and realistic conditions. The combination of Generative Artificial Intelligence and Extended Reality technologies is facilitating the development of intelligent virtual tutors, adaptive simulations and personal learning environments. Virtual Reality is becoming increasingly popular in educational institutions in order to simulate scientific experiments, historical events, and workplace environments, and Augmented Reality is being applied to superimpose digital information on physical objects and the classroom. It is believed that in the future, higher education systems will be very dependent on the Extended Reality technologies to facilitate experiential learning and skills development, as well as workforce preparation.

#### Digital Twins and Simulation Technologies

Digital Twins represent the new state of the art educational technologies that enable educational institutions to build virtual models of classrooms, labs, industrial systems, and learning environments. The technologies are especially helpful in the engineering, healthcare and scientific education as they enable students to test the complex systems in safe and controlled environments. Digital Twins are able to model equipment failures, environmental variations, and physical world conditions, which would be costly or unsafe to re-create in reality. When Generative Artificial Intelligence is combined with Digital Twins, this type of systems will become more interactive, predictive, and adaptive. Digital Twins with AI can be dynamically responsive to the choices of students, create new conditions on the fly, and give individual advice on the simulation. These technologies should gain even greater significance as learning institutions are pursuing more hands-on and practice-based models of learning.

### Diffusion Models and Generative Adversarial Networks

Diffusion Models and Generative Adversarial Networks are gaining prominence as educational technologies since they have the capability to produce realistic images, videos, diagrams, animations, and simulations. Such technologies prove to be of great use especially in the development of educational material in science, medicine, engineering, design, and creative arts. Diffusion Models are capable of producing high-quality visual learning content using simple text input, whereas Generative Adversarial Networks are capable of producing artificial datasets, simulated worlds, and simulated environments. The technologies are also increasing the opportunities of customized learning material due to the fact that the instructors can create customized diagrams, laboratory illustrations, and other visual explanations depending on the needs of the learner. Nonetheless, there are issues of misinformation, deepfakes, and authenticity as well when it comes to the application of synthetic media technologies, particularly in educational environments where trust and accuracy are paramount. The next generation of educational governance systems will thus probably consist of policies to regulate the use of AI-generated visual content.

### Learning Analytics, Blockchain, and Federated Learning Technologies

The technologies of Learning Analytics are gaining more significance due to their ability to track the performance of students, reveal the learning gaps, and forecast the academic performance. These technologies are based on the ongoing gathering and processing of the data on student interaction in order to enhance the decision-making and individualized teaching [43-45]. Learning Analytics systems are becoming more and more intertwined with Generative Artificial Intelligence to offer automatic suggestions, predictive notifications, and feedback. There is also interest in education related to blockchain technologies since academic credentials, learning records, and assessment results can be stored safely. Blockchain systems enhance transparency and eliminate credential fraud risk and lifelong learning portfolios. Moreover, Federated Learning technologies are becoming one of the most important solutions to secure data about students. Federated Learning enables AI systems to be trained with data shared in different institutions without explicitly transferring sensitive information, and is especially useful in collaborative educational research projects and larger-scale analytics projects.

### Explainable AI, Ethical AI, and Governance Technologies

Explainable Artificial Intelligence technologies are becoming more and more required since educators and students should know the way how Generative Artificial Intelligence systems decide. Explainable AI technologies have the ability to provide the reason behind making a recommendation, the calculation of a grade, or the identification of a student as being at academic risk. This openness is crucial towards gaining confidence in AI-based education systems and promoting equitable and responsible automated decision-making. These technologies are directly related to the larger issues of AI Ethics, bias detection, privacy protection and institutional governance. More recent developments have indicated that educational institutions have started to shift out of the isolated AI experimentation to officially governed frameworks of education that encompass ethical standards, staff education, and policy formulation. The use of AI among students in many schools is still without a proper regulation despite the fact that it is still increasing at an alarming rate. It emphasizes the increasing significance of Explainable Artificial Intelligence and ethical governance technologies as the key elements of the Future of Education.

### *3.4 Artificial intelligence models*

#### Large Language Models in Education

The most actively discussed AI models in the educational research at the moment are Large Language Models, which are able to produce text, summarize, answer questions, assist with coding, and produce teaching resources in real time. These models are based on the large scale pretraining with wide range of textual data and can be further customized to subject-specific educational tasks [9,46-48]. Large Language Models are becoming popular within the educational setting to generate lesson plans, generate quizzes, give feedback on writing, translate texts, and other tutoring systems. Their ability to imitate

conversational speech has seen them particularly applicable in online learning, distance education and in teaching multilingual settings. It is also evident that in recent times, Large Language Models are being incorporated into institutional platforms to assist in advising, assessment, and curriculum planning. Still, the issue of hallucination, misinformation, inconsistency of facts, and inappropriate use of automated outputs stays. The newer applications of education are more inclined towards retrieval-enhanced and domain-specific models to enhance accuracy and relevance of facts.

#### Transformer Models and Attention-Based Architectures

Transformer Models: the transformer models are the most prevalent architectural model of most Generative Artificial Intelligence systems applied in education. These models are based on the mechanism of self-attention enabling them to cope with the long sequence of texts, find long-range contextual relations, and produce coherent answers to multiple interactions. Transformer Models have been greatly useful in improving educational processes like automated essay grading, summarization, language translation, conversational tutoring and content generation. Their capacity to work with long texts and interpret intricate situations makes them particularly helpful in tertiary education, where students have to deal with lengthy texts, scholarly articles, and expertise-related contents. Recent trends indicate that transformer architectures are increasingly more efficient, and smaller and more specific educational versions are being developed to be deployed to individual institutions and to be less expensive in terms of their computation.

#### Foundation Models for Educational Ecosystems

The emergence of Foundation Models is becoming a prominent type of AI models since it can be used to perform several educational activities on the same generalized architecture. In contrast to the previous systems, which were created to execute a single task, Foundation Models can perform tutoring, summarization, translation, recommendation, content generation, and predictive analytics [49-50]. Their compatibility makes them especially appealing to schools and universities that want to have all-encompassing AI ecosystems and not a collection of separate tools. According to the current trends in education, the institutions are shifting towards Foundation Models as they can be configured to various disciplines and classes of learners without the need to have different systems that can handle a single task. The expansion of Foundation Models is indicative of the general trend of moving towards AI platforms that can support the entire student lifecycle, including admissions and onboarding through advising, assessment, and lifelong learning.

#### Multimodal Artificial Intelligence Models

The Multimodal Artificial Intelligence models gain more and more significance due to the fact that they unite text, image, audio, video, and behavioral information into one system. The models can be applied particularly in the field of education since learning may take various forms of interaction and not only text. Multimodal models are able to interpret student speech and handwriting, facial expressions, classroom activity and uploaded illustrations and at the same time build answers in multiple mediums. They can be useful in science education, language learning, healthcare training, engineering, and creative subjects due to such capabilities. Recent literature emphasizes the increasing applications of multimodal models in the educational feedback, immersive learning and adaptive tutoring. The most popular arguments among researchers are that the future of educational AI will be based on models that can interpret several types of learner behavior in contrast to the models that may be based on text only.

#### Mixture of Experts Models for Scalable Educational AI

The importance of Mixture of Experts models is growing since they separate complex AI tasks into various specialized sub-models instead of using one general-purpose network. The application is especially useful in the educational setting, where various learning activities demand various expertise [40,51,52]. One of the expert models can be language tutoring, another might be mathematics, another one is coding, and another one is emotional analysis. Mixture of Experts architectures are also becoming the source of effective AI implementation since they decrease computation needs and enhance task-related performance. These models are likely to be used more in educational institutions as they will

enable the systems to offer more personalized and specialized support in various subjects and require learners to meet. More recent findings with multimodal large language models also indicate that Mixture of Experts techniques can enhance reasoning, multimodal interpretation and scalability.

### Retrieval-Augmented Generation Models

RAGs are gaining more and more popularity in the educational field since they enhance the factual accuracy of AI-generated information, accessing the information of reliable external sources and producing answers. The traditional Large Language Models tend to use the internal training data only, which may result in outdated or wrong information. To minimize this issue, Retrieval-Augmented Generation models are linked to institutional databases, textbooks, lecture notes, academic repositories, and curriculum documents. These models are especially applicable in educational institutions in the form of tutoring, advising, library support and specialized subject support since one can get a response based on proven content. According to current educational experiments, Retrieval-Augmented Generation models have been shown to be more successful than general-purpose chatbots in special courses where accuracy in facts and alignment with curriculum are the crucial factors.

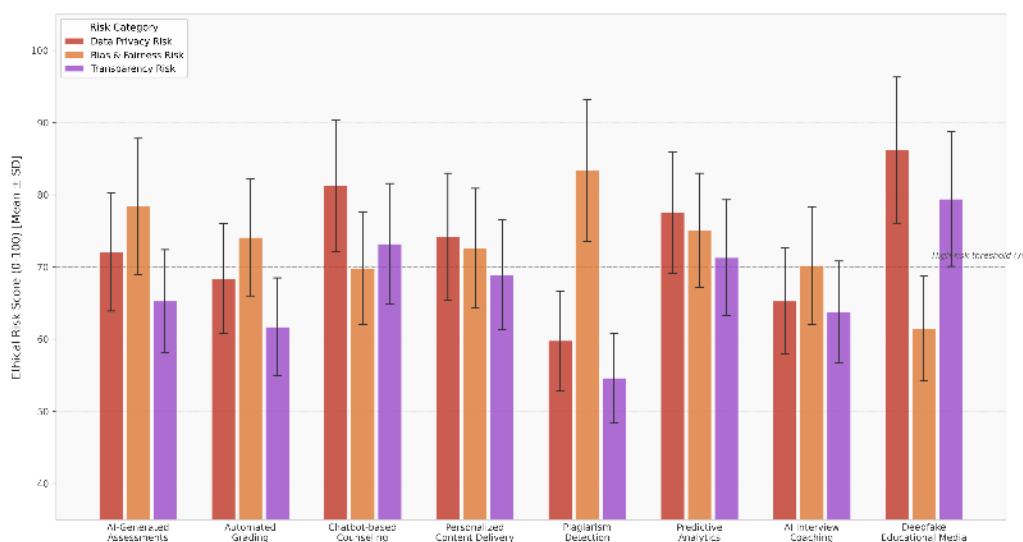


Fig.5 Error Bar Plot: Ethical Risk Scores of Generative AI Applications in Education (Mean +/- SD)

Fig.5 is a error bar chart quantifies and compares the perceived ethical risk of eight generative AI applications in education across three risk dimensions: data privacy risk, bias and fairness risk, and transparency risk. For each application and risk category, bars represent group mean scores derived from expert-rated survey instruments, while black error bars denote one standard deviation in each direction, providing a statistically meaningful representation of inter-rater variability. A horizontal dashed reference line at the score of 70 denotes the adopted high-risk threshold, enabling rapid identification of applications exceeding acceptable risk limits. Deepfake educational media and chatbot-based counseling consistently surpass this threshold across multiple risk categories, raising significant concerns about content authenticity and psychological vulnerability of learners. Automated grading systems present moderate levels across all three dimensions, warranting careful algorithmic auditing. The chart reveals that data privacy risk is most severe for AI-powered counseling tools, while bias and fairness risk peaks in AI-generated assessments and plagiarism detection, both of which have direct consequences for equitable academic evaluation.

### Diffusion Models for Visual Educational Content

Diffusion Models are currently becoming essential in the education generation of content since they are capable of producing realistic images, diagrams, animations, and simulations based on simple text

instructions. The models have been found to be especially helpful in fields like medicine, engineering, science, and design where visual representation is necessary to the comprehension of complex ideas. Diffusion Models have the ability to produce illustrations in laboratories, anatomical models, past recreations, and architectural sketches that aid more interacting learning. Diffusion Models are more realistic, high-resolution, and more predictable, compared to the previous methods of image-generation. Their increasing popularity in education is an indication of the larger trend of the multimodal learning environment where students are exposed to visual and textual materials at the same time.

#### Generative Adversarial Networks for Simulation and Digital Humans

Generative Adversarial Networks continue to be significant AI models due to the ability to produce realistic images, avatars, as well as virtual environments, through two neural networks competing with each other. Generative Adversarial Networks are gaining popularity in education with applications in digital humans, realistic classroom simulation, virtual tutor and synthetic training data [53-56]. Medical education, language learning and professional training are the specific areas where these models come in handy since they allow the learners to engage themselves with the virtual world that is realistic, without the need of physical resources. The recent studies in education show that Generative Adversarial Networks can be combined with vision transformers and multimodal interfaces to generate interactive online human environments that can be used to promote individualized learning and interactions.

#### Federated Learning Models to Privacy-Preserving Education.

Federated Learning models gain more and more significance due to the ability to train AI systems on the basis of student data provided in a variety of schools or institutions without transferring sensitive data to each other. This model is especially useful in the education field since records about students most of the times contain extremely sensitive personal, behavioral, and academic details. Federated Learning can be used to develop models collaboratively and minimize privacy risks and meet the institutional data governance needs. Increasingly, researchers consider Federated Learning to be the key to the future of educational ecosystems since in this way, institutions will be able to gain the benefits of large-scale AI training without giving up local control over their data. Recent research also emphasizes the appearance of federated multimodal foundation models, which are able to combine text, images, audio, and behavioral data in a decentralized educational setting.

#### Explainable AI Models for Transparent Learning Systems

It is increasingly becoming that explainable Artificial Intelligence models are required since educators and students require knowledge of how AI systems make their decisions on aspects of grading, feedback, recommendations, and predicting academic risks. Explainable AI models offer clear outputs that aid users in comprehending why a struggling learner was categorized so or why a specific recommendation was given or how a grade was produced [57-59]. Such transparency is especially needed in high stakes situations in education like admissions, scholarship awards, and performance appraisals. According to emerging research in education, explainability is also being replaced by non-technical explanations that are more personalized, multimodal and user-centered to accommodate various audiences like teachers, students and administrators.

#### Adaptive Learning and Intelligent Tutoring Models

One of the most established AI models in the educational field is Adaptive Learning and Intelligent Tutoring Systems models since they are able to tailor the instruction based on the needs, performance, and speed of the learner. These models help study the interaction of students, find out the wrongful assumptions, and support them individually in real time. Mathematics, language learning, science education, and professional training Adaptive Learning models have been applied widely as they are able to dynamically change the difficulty of the content and the learning path. The recent changes suggest that these models are getting more advanced with the incorporation of Large Language Models, multimodal analytics, and emotional recognition. This is making a new generation of smart tutoring systems that can offer more human-like, context-sensitive and interactive educational experiences.

#### Domain-Specific Educational Models and the Future of AI in Education

Specialized educational AI models are gaining importance due to the fact that general purpose models do not always have the contextual knowledge needed by the specialized academic disciplines. Institutions are thus coming up with smaller and focused models, which are trained on curriculum-related materials, disciplinary vocabularies, and institutional documents [6,60-62]. Such models have found application especially in the medical field, engineering, law, business and research in the field of science where precision and contextual accuracy are crucial. Domain models may offer more credible advice, enhanced tutoring assistance, and enhanced compliance with the local educational goals. There are current trends that future work in the field of educational AI will be in the form of layered ecosystems where general-purpose Foundation Models are integrated with smaller, custom-made models specific to a course or role or institution. This method is becoming considered more cost efficient, secure and pedagogically pertinent than the use of large generic systems only.

### *3.5 Artificial intelligence applications*

#### Personalized Learning Applications

One of the most important uses of Generative Artificial Intelligence in the educational process has become Personalized Learning since AI systems are capable of customizing content, speed, form of assessment, and feedback based on the profile of particular learners. Larger Language Models and predictive analytics are becoming increasingly applied to modern educational platforms to provide students with different academic capabilities and learning preferences with individualized study plans, adaptive exercises, and personalized explanations. The applications have been particularly useful in the higher education, online learning as well as professional training settings whereby students usually demand various forms of assistance. According to recent trends in education, the trend of AI-powered personalization is shifting toward non-statically recommended suggestions to more adaptive learning experiences based on instant and continuous adjustments based on student engagement and performance and emotional reactions. Personalized learning is becoming an important trend in educational institutions as a means to enhance retention, enhance satisfaction in learning, and eliminate performance disparities between students of varying backgrounds and abilities.

#### Adaptive Learning Systems and Smart Study Pathways

The adaptive Learning applications are getting more advanced as they are able to adjust the difficulty of the lesson, the content sequence, and teaching techniques according to the performance of learners. These systems are based on the principles of Machine Learning and Learning Analytics to detect the knowledge gaps and suggest the specific intervention to prevent the development of academic issues to critical levels [55,63-65]. The adaptive learning applications find application especially in mathematics, language learning, science education and professional certification programs since students are able to learn at their own pace. The recent advancements of adaptive systems include AI-generated study plans, 24-hour tutoring, and dynamically-generated content that adapts to the strengths and weaknesses of a learner. The rise of such applications is indicative of a larger trend to break out of the one-size-fits-all education approach to highly personalized educational paths that are meant to help learners get as much out of education as possible.

#### Intelligent Tutoring Systems and Virtual Tutors

Intelligent Tutoring Systems have become some of the most popular uses of Generative Artificial Intelligence since they approximate one-on-one teaching and offer students personalized, immediate instructions. The AI-based tutor is able to respond to questions, give explanations, create practice problems, and provide feedback whenever needed and is especially helpful in remote education and blended learning. There is a growing adoption of these applications in STEM education, coding education and language education and exam preparation since they can provide a scalable support without necessarily having a teacher available on demand. New trends in the educational sector indicate that AI tutors will become more than just a mere chatbot and will be more advanced to remember the long-term, adjust to the emotions of the learner and respond to their needs with a high degree of context.

The Future of Education is also experiencing a rise in the adoption of AI tutoring in official learning systems by many institutions as the significance of virtual educational assistants grows.

#### Automated Assessment and Feedback Applications

Assessment Automation is emerging as one of the most powerful uses of Generative Artificial Intelligence since it allows teachers to offload their work and offer more valuable and prompt feedback to students. AI systems are becoming popular in grading essays, scoring short answers, creating rubrics, and giving formative remarks that enable students to make their work better. Such applications can be of great use in big classrooms or online courses where teachers might not be able to respond to students on a one-on-one basis in a short time. Writing style, grammar problems, plagiarism, and revisions can also be analyzed automatically and with the help of assessment tools. Nevertheless, the increased application of AI in evaluation has also questioned the topics of fairness, prejudice, and transparency as well as the effectiveness of automated grading programs. The future educational assessment model will probably involve the integration of AI-generated assessment and human control to guarantee accuracy and accountability.

#### Content Generation and Curriculum Development Applications

Large Language Models are used more and more to create learning content in the form of lesson plans, quizzes, case studies, assignments, lecture notes, and discussion prompts. The applications are changing the curriculum design process since it enables an educator to develop instructional materials more fast and tailor it to the needs of a certain group of learners [66-67]. AI generated content can be particularly helpful in multilingual education and competency-based learning and skills-based training where educators need a significant volume of customized content. The current tendencies indicate that the process of content generation is getting more and more artificial, as AI helps to draft, translate, label, and make items, and teachers have to keep the quality intact and the pedagogical correctness on the required level. This collaborative model is likely to be more prevalent as the institutions shift to experimental uses of AI to more systematic and sustainable implementation plans.

#### Learning Analytics and Predictive Applications

Learning Analytics software applications can help educational institutions to track student engagement, risks in academics, and factor in more informed choices related to teaching and support services. The attendance records, assignments, and discussion, and assessment results can be analyzed with AI systems and identify the students who might need intervention. The predictive analytics application is increasingly applied to enhance the retention rates, lessen the risk of dropouts, and determine the factors that are related to the academic success. Their applications are particularly useful in large universities and online learning where teachers do not have the opportunity to interact with students on a regular basis. The more the Generative Artificial Intelligence is becoming part of learning analytics, the more automated alerts, personalized recommendations, and predictive dashboards are being used by institutions to be even more proactive in the support of student success.

#### Multimodal Learning and Immersive Educational Applications

The applications of Multimodal Artificial Intelligence are on a high growth rate due to the integration of text, image, audio, video, and interactive media in one learning environment. The applications are particularly popular in science, engineering, medicine, design, and language education since they enable students to interact with educational material using more than one channel of sense [68-70]. Multimodal AI systems are able to process diagrams, understand speech, create narrated explanations and create simulation experiences that enhance comprehension of complex concepts. The increased application of Virtual Reality, Augmented Reality, and digital twins also supplement the role of multimodal learning by providing real-life situations where students have the opportunity to practice their skills and explore situations that would be hard or costly to reproduce otherwise. The new studies show that multimodal AI can become one of the most significant future trends in educational technology as it facilitates the accessibility, engagement, and more substantial learning experiences.

#### Language Learning and Translation Applications

GAI has gained particular significance in the teaching of languages due to its ability to correct grammar, offer pronunciation feedback, translate, learn new vocabulary, and chat. Language applications powered by AI have the potential to mimic a natural conversation, correct users instantly, and give them exercises that meet their specific needs. The applications prove especially useful to students studying English or other foreign languages since they provide them with an opportunity to practice it constantly even when they are not in the classroom. The recent developments in speech recognition and multilingual Large Language Models have enabled the quality of AI-assisted language learning to become considerably higher, which makes educational systems more accessible to students with various linguistic backgrounds. Also, the use of language learning applications is actively implemented in the field of international education and cross-border online learning in which translation and multilingual communication are a critical component.

#### Administrative and Institutional Applications

Generative Artificial Intelligence has been applied in other areas of life outside of classroom education to assist with the administration and decision making in institutions. Schools are implementing AI systems to automate the admissions process, classes, respond to student requests, record management, and academic advising [71,72]. Chatbots and virtual assistants are common in assisting students in enrolling into courses, applying to financial aid, and choosing courses. These administrative applications save on the costs of operation and enhance efficiency of the educational services particularly in institutions with high student population. The current trends indicate that AI is integrated into the larger institutional structure and is not confined to isolated teaching tools anymore. The growing applications of AI in the admissions, planning, and student support show that Generative Artificial Intelligence is transforming the whole educational ecosystem.

#### Coding Education and Programming Support Applications

Generative Artificial Intelligence is becoming a tool used in computer science and in programming education in general since it is able to generate code, describe algorithms, debug errors and give step-by-step instructions to students. The applications can be particularly useful to novice programmers who might have problems with syntax, logic, and debugging. The AI can assist with the instant feedback on program assignments, and suggest ways to improve it, as well as the role of a teaching assistant. Generative Artificial Intelligence is also used in computing education, where it is taught to learn prompt design, algorithmic thinking and collaborative code practices. The recent trends state that the role of AI-assisted programming education will gain in significance as students will have to acquire the skills to operate not only in codes but also in collaboration with AI equipment in their future jobs.

#### Academic Integrity and Plagiarism Detection Applications

The use of Generative Artificial Intelligence to write, code, and prepare assessment has caused the use of Academic Integrity applications to become ever more relevant. Schools are coming up with AI-based plagiarism detectors, authorship detectors and content-checking algorithms to overcome original student work and AI generated content [36,73-75]. The applications are especially essential since adoption of AI has rapidly upset the conventional assessment practices and brought up the issues of cheating, authenticity, and excessive reliance on technology. Recent debates indicate that educational assessment in the future may comprise of more oral assessment, project based learning and demonstrations in the classes to make sure that students are actually learning what they are handing in. Academic policies are also starting to become more explicit on the acceptable level of AI use as the relevance of Academic Integrity in the era of Generative Artificial Intelligence increases.

#### Digital Literacy, Human-AI Collaboration, and Future Educational Applications

Digital Literacy and Human-AI Collaboration is the focus application of Generative Artificial Intelligence since educational institutions are starting to acknowledge that students should learn how to use AI in a responsible and effective manner. However, instead of viewing AI as a content generation tool, a significant number of schools and universities are starting to introduce AI literacy, prompt engineering, critical thinking, and ethical consciousness to the curriculum. New policy debates are

emerging that state that AI ought to be considered as a fundamental educational skill just as digital literacy or computational thinking. Educational reforms in India already arrange to deliver AI and computational thinking content into school curriculum as early as possible, as the value of being AI literate is increasingly being appreciated as a requirement to be employable and a citizen in the future. It is probable that in the future, education will focus on Human-AI Collaboration but not on mere automation because it is necessary to keep students creative, emotionally intelligent, thinking critically, and with moral sense in addition to the technical AI expertise.

#### **4. Discussion**

The literature reviewed shows that Generative Artificial Intelligence has become not only an additional technological tool but also a core element that transforms the educational system, pedagogical process, the organization of institutions, and the future training of the labor force. Generative Artificial Intelligence is being integrated into teaching, learning, assessment, content generation, advising, and student support services across schools and universities and online learning settings. The literature review shows that the emergence of Large Language Models, multimodal systems, and predictive educational analytics has greatly propelled the revolution in education by allowing more personal, efficient, and accessible learning experiences [9,46-48]. But this change is also supported by equally important ethical, pedagogical, and governance challenges. According to recent research, the global research context in the field of Generative Artificial Intelligence in education is rapidly expanding in the period of 2022-2025, and the interest in the evaluation of academic integrity, institutional policy, teacher preparedness, and the long-term impact of educational quality is growing. Among the most important discoveries made throughout the literature is the rising importance of Personalized Learning and Adaptive Learning in determining the experience of students. It is now possible to have AI-assisted educational systems that personalize content, feedback, learning pace, and instructional support based on the needs of individual learners, their performance in school, and engagement patterns. Such a change of individualized education can be especially useful to those learners who have other language backgrounds, disabilities, or learning styles. Simultaneously, the literature suggests that the quality of learner data, the fairness of algorithms, and the capacity of educators to interpolate and take AI-based insights are critical to the effectiveness of personalized learning. The future of personalized learning is also being noted by emerging studies to depend more and more on emotionally aware tutoring systems, multimodal learning environments, and real-time behavioral analytics.

It is also discussed that Intelligent Tutoring Systems and conversational AI tools gain more and more significance in helping learners during the hours that do not involve a real classroom. These systems have the capability of giving real-time feedback, replicating one-on-one tutoring, generating study materials, and responding to student questions in bulk. Nonetheless, the majority of investigations overwhelmingly state that AI technologies must supplement and not substitute teachers. Human-AI Collaboration is the most long-lasting model that is mentioned in the literature as the future of education in which teachers remain to offer emotional support, ethical guidance, pedagogical judgment, and contextual insight, and AI performs repetitive and scalable tasks. This blend model is seen more and more as the key to keeping trust, human relationships intact, and avoiding excessive reliance on automated systems. One of the key issues that are running through the literature is the increasing challenge of Academic Integrity. The emergence of AI-written essays, reports, code, and assignments have made conventional assessment and authorship practices more difficult. Generative AI tools are becoming more popular with students doing coursework without having a well-conceived idea of what is ethical and what is not. Recent research has shown that most institutions are still not ready to handle the fast rate of adoption of AI, which leads to the confusion of the use of AI that is acceptable, the disclosure of authorship, and the issue of academic honesty. A number of recent studies also indicate that few students are formally taught about ethical AI use, and many educators do not feel confident about dealing with AI-related misuse. This growing gap between technology adoption and institutional preparedness highlights the need for more comprehensive AI literacy programs, clearer academic integrity policies, and redesigned assessments that emphasize authentic learning and critical thinking.

It can also be seen in the literature that the fast introduction of Generative Artificial Intelligence provokes significant issues related to AI Ethics, Data Privacy, and Algorithmic Bias. Learning AI systems often use numerous sensitive student data, such as academic history, school attendance, engagement and behavioral measures, and individual data. The lack of robust governance systems can subject learners to privacy, bias, and discrimination. Recent studies point out that most of the existing AI systems lack transparency and they tend to be biased by the training data. Marginalized students are particularly concerned with these problems since they may be disproportionately impacted by biased recommendations, predictive analytics, or automated risk classifications. Consequently, there is an increased demand in the literature to have explainable AI systems, privacy-sensitive architectures, and more robust ethical principles that position equity, transparency, and inclusion as the core of AI implementation. Another fact pointed out in the discussion is that the adoption of AI is changing the place of teachers and Digital Pedagogy considerably. A lot of teachers are now supposed to learn about prompt engineering, assess AI-generated materials, redesign tests, and educate students about how to use AI responsibly. Nonetheless, the latest research shows that the readiness of teachers has been weak, as most of them are not sure how to implement AI into their practice successfully. According to various reports, faculty members are becoming more and more anxious that students are turning into extreme reliant on AI tools, which result in less and less developed writing abilities, shorter attention span, and poorer critical thinking skills. There has also arisen the notion of false mastery, which can be defined as a scenario where students seem to have done well due to the fact that AI is able to produce high-quality results on their behalf, although they might not be having a proper grasp of the content they have been taught. These issues support the significance of developing high-level pedagogical practices and creating learning experiences that promote reflection, creativity, and autonomous thinking.

Table 1. Summary of Major AI Applications, Opportunities, and Challenges in Education

<b>Sr. No.</b>	<b>Application Area</b>	<b>Opportunity</b>	<b>Major Challenge</b>
1	Personalized Learning	Customized content and pacing	Biased learner profiling
2	Adaptive Learning	Real-time intervention and support	Unequal data quality
3	Intelligent Tutoring Systems	Continuous feedback and tutoring	Overdependence on AI
4	Assessment Automation	Faster grading and evaluation	Fairness and transparency concerns
5	Content Generation	Rapid lesson and quiz creation	Misinformation and hallucination
6	Learning Analytics	Early risk detection	Privacy and surveillance concerns
7	Language Translation	Improved multilingual access	Loss of contextual meaning
8	Speech Recognition	Greater accessibility	Accent and dialect bias
9	Computer Vision	Engagement monitoring	Surveillance and consent risks
10	Administrative Chatbots	Faster student services	Limited contextual understanding
11	Coding Assistants	Better programming support	Reduced independent problem-solving
12	Virtual Laboratories	Enhanced practical learning	High implementation cost
13	Digital Twins	Immersive simulations	Technical complexity
14	AI Research Support	Faster literature synthesis	Risk of fabricated information
15	Plagiarism Detection	Improved academic honesty monitoring	False positives and inaccuracies
16	Multimodal Learning	More engaging learning experiences	High infrastructure requirements
17	Accessibility Tools	Better inclusion for disabled learners	Dependence on proprietary platforms
18	Predictive Analytics	Improved student retention	Stigmatization of at-risk students
19	Curriculum Design	Faster instructional planning	Overstandardization of content
20	Student Advising Systems	Better academic guidance	Lack of human empathy

There is a strong indication in the literature that the future educational systems will demand more holistic ways of Digital Literacy that go beyond technical competence. Students and educators are also becoming more and more required to learn not only about the usage of AI tools but also about how to challenge them, assess their output, detect misinformation, and notice ethical issues. Recent research suggests that AI literacy can be considered as significant as the traditional digital literacy since the future employment requirements will dictate that learners will need to collaborate with AI systems creatively, ethically, and collaboratively. The scientific community is gradually suggesting that AI ethics, data literacy, prompt engineering, critical evaluation, and algorithmic awareness must become part of the educational curriculum in the future. Such a change is especially significant as some recent studies indicate that the institutions that merely teach prompt-writing skills might not prepare students with a deeper knowledge of how AI systems work and how they influence society.

Table 2. Future Directions, Policy Needs, and Emerging Research Areas

<b>Sr. No.</b>	<b>Area</b>	<b>Future Direction</b>	<b>Policy Need</b>
1	AI Literacy	Integrate AI across curricula	National AI competency frameworks
2	Assessment	Shift toward authentic evaluation	Institutional assessment redesign
3	Academic Integrity	Develop AI disclosure standards	Clear plagiarism and attribution policies
4	Teacher Training	Expand AI professional development	Mandatory staff training programs
5	Data Privacy	Introduce privacy-preserving AI	Stronger data governance rules
6	Bias Mitigation	Develop fairer AI systems	Equity audits and monitoring
7	Human-AI Collaboration	Promote hybrid teaching models	Teacher-centered AI implementation
8	Personalized Learning	Improve emotional and behavioral analytics	Ethical learner profiling rules
9	Multimodal Learning	Expand immersive educational experiences	Infrastructure investment
10	Accessibility	Improve AI for diverse learners	Inclusive technology regulations
11	Research Integrity	Establish AI use disclosure in publications	Standardized research ethics guidelines
12	Institutional Governance	Create AI oversight committees	University-level governance frameworks
13	Cybersecurity	Protect educational AI systems	Secure AI infrastructure policies
14	Student Well-Being	Monitor emotional effects of AI dependence	Mental health safeguards
15	Workforce Readiness	Align curricula with AI-era jobs	National employability strategies
16	Explainable AI	Improve transparency of AI decisions	Explainability standards
17	Cross-Cultural Research	Study AI use across regions	International collaboration policies
18	Lifelong Learning	Expand AI-supported adult education	Flexible credential frameworks
19	Inclusive Education	Reduce technology access gaps	Public funding for underserved regions
20	Future of Education	Build human-centered AI ecosystems	Long-term educational transformation strategies

In general, it can be suggested that the Future of Education will be determined by the possibility of educational institutions to combine technological innovation and ethical accountability, human-focused design, and inclusive governance. Although Generative Artificial Intelligence will have enormous opportunities to enhance teaching, learning and administration, the long term usefulness will be determined by how well institutions handle issues associated with academic dishonesty, privacy, equity, and student welfare. The future studies should thus address longitudinal effects, emotional and cognitive consequences, institutional preparedness, and formulation of governance structures that are conducive to safe, transparent, and equitable adoption of AI in education.

## 5. Conclusions

This systematic review has shown that Generative Artificial Intelligence is transforming the educational systems at a very fast rate by bringing new types of content creation, automation of assessment, adaptive learning, and Human-AI Collaboration. In the literature reviewed, Generative Artificial Intelligence has become one of the leading innovations in education, especially in the context of the combination of Large Language Models, intelligent tutoring systems, and personalized learning environments. These technologies are becoming progressively helpful in allowing teachers to develop individual instructional content, generate formative evaluations, offer immediate feedback, and decrease monotonous administrative expenses. Meanwhile, students also enjoy more access to interactive learning materials, personalized explanations, and customized learning options that suit their individual learning requirements and wants. The review also points out that Artificial Intelligence in Education is becoming one of the key elements in the digital pedagogy today and is potentially going to dominate the future of education. But the results also indicate that the fast pace of implementing Generative Artificial Intelligence also poses significant ethical, social, and institutional problems that should not be ignored. Academic integrity, misinformation, bias in algorithms, and a lack of transparency, data privacy, and unequal access are some of the most important obstacles to responsible adoption. The concept of AI-generated assignments, automated essay writing, and machine-generated content has amplified the controversy of plagiarism, authenticity, and the loss of critical thinking abilities. Moreover, even now, a lot of institutions do not have a detailed policy on AI governance, a set of ethical guidelines, and enough training on digital literacy among educators and students. In the absence of proper protection, the growing dependence on Generative Artificial Intelligence can exacerbate current educational disparities, strengthen biases in training data, and decrease the possibility of human interaction in the teaching and learning contexts.

It is also proposed in the review that upcoming educational systems should not place Generative Artificial Intelligence as an alternative to teachers, but as an aid that helps teachers to perform better and students to interact with them better. Human-AI Cooperation must always be at the core of the educational practice, and educators should have control over the design of the curriculum, ethical choices, assessment plans, and pedagogical decision-making. The next approach to research should be longitudinal studies to investigate the long-term consequences of Generative Artificial Intelligence on the performance of students, their creativity, emotional growth, and their capability to think higher-order. There is also a need to conduct additional research on AI ethics, patterns of cross-cultural adoption, inclusive design, and the design of transparent regulatory frameworks that promote accountability and fairness. Since educational institutions are running to embrace the use of Generative Artificial Intelligence, a rational balance between innovation, ethical accountability, digital literacy, and human-focused pedagogy will be needed to realize sustainable and equitable educational change.

### Conflict of interest

The authors declare no conflicts of interest.

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