Artificial intelligence will empower education in 2025: From auxiliary tools to collaborative partners

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Abstract. 2025 marked a pivotal turning point of explosive growth and deep integration of artificial intelligence (AI) technology in the education sector. The role of AI in education is undergoing a systematic shift from traditional "standardized teaching assistance" to "personalized human-machine collaborative enhancement." This article examines the core advancements in AI-driven education during the year, focusing on four key areas: generative AI (GenAI), intelligent teaching agents, edge AI educational hardware, and educational AI governance frameworks. Research indicates that the global educational AI ecosystem demonstrates a trend of balancing technology-driven innovation with educational equity. The study concludes that the current priority has shifted toward the compliant deployment and engineering implementation of AI technologies in educational settings. Future educational paradigms will emphasize the synergy of "AI + Human Intelligence (AI+HI)," propelling AI beyond a mere efficiency tool to evolve into a "human-machine collaborative augmented educational partner" that promotes students' holistic development and enables truly personalized, adaptive teaching.

Keywords: AI Education; Intelligent Teaching Agents; Generative AI; AI Governance in Education; Personalized Learning

1. Introduction

1.1 Research Background

Following the initial accumulation of perceptual and analytical intelligence, artificial intelligence (AI) technology witnessed the explosion of generative AI (GenAI), represented by large language models (LLMs), between 2024 and 2025. Against this backdrop, the digital transformation in the field of education has also advanced from the "tool-stacking" phase into a new stage of "cognitive empowerment." The United Nations Educational, Scientific and Cultural Organization (UNESCO) points out that the educational application of generative AI has become the most significant variable for the future reform and development of education [1]. Currently, AI not only effectively alleviates the uneven distribution of educational resources but also significantly enhances students' learning efficiency and teachers' precision in teaching and research through adaptive learning algorithms. However, the rapid iteration of technology also subjects education systems to unprecedented challenges, such as ethical scrutiny, data privacy, and algorithmic bias.

1.2 Concept Definition of AI Education

AI Education (AIED) refers to the deep interdisciplinary integration of artificial intelligence, computer science, and fields such as pedagogy and cognitive psychology. The “AI + Education” discussed in this study specifically pertains to the theory and practice of intelligently upgrading key educational processes—teaching, learning, assessment, evaluation, and administration—through the use of technologies such as machine learning, natural language processing (NLP), knowledge graphs, and generative large models [2].

To comprehensively grasp this conceptual framework, it is crucial to recognize that AIED encompasses two distinct yet interconnected dimensions: learning about AI (which focuses on cultivating students' AI literacy, algorithmic comprehension, and computational thinking) and learning with AI (which involves deploying intelligent systems to augment pedagogical environments). This study predominantly investigates the latter—the systemic application of AI as a transformative educational infrastructure. By embedding principles of cognitive psychology, AI facilitates a paradigm shift from traditional behaviorist models of education, often characterized by

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rote memorization and standardized delivery, toward constructivist and connectivist learning environments. In this advanced framework, artificial intelligence functions as an adaptive cognitive scaffold, continuously calibrating its instructional support to align with the individual learner's Zone of Proximal Development (ZPD).

The realization of this definition relies heavily on the synergistic orchestration of specific underlying technologies. Natural Language Processing (NLP) and Generative Artificial Intelligence (GenAI) serve as the communicative interface, enabling fluid, conversational interactions that closely replicate human tutoring. Unlike early educational software reliant on rigid, pre-programmed decision trees, generative models can interpret semantic ambiguities, assess the underlying intent of a student's query, and synthesize contextually nuanced explanations in real time. Simultaneously, Knowledge Graphs provide the structural and epistemological backbone of the system. By mapping complex ontological relationships between disparate academic concepts, knowledge graphs work in tandem with machine learning algorithms to dynamically trace a student’s cognitive trajectory. This allows the system to pinpoint precise knowledge gaps and instantly recommend targeted remedial content, thereby achieving granular, micro-level personalization.

Furthermore, the "AI + Education" paradigm fundamentally redefines traditional approaches to educational assessment and institutional administration. Conventional summative evaluations, which are inherently retrospective and static, are rapidly being supplanted by continuous, AI-driven formative assessments. Through Multimodal Learning Analytics (MMLA), these intelligent systems seamlessly capture and analyze a wide array of learning data points—such as linguistic complexity in student essays, problem-solving latency, and interactive behavioral patterns—to construct a comprehensive, real-time diagnostic profile of student mastery and engagement.

On the administrative front, educational intelligence transitions institutional management from a reactive stance to a proactive strategy. Machine learning models analyze vast longitudinal datasets to accurately forecast potential student attrition, optimize campus resource allocation, and identify systemic instructional inefficiencies across different demographic groups.

Ultimately, the concept of AI Education in the contemporary era transcends the mere digitalization of analog classrooms. It represents a sophisticated socio-technical ecosystem meticulously designed to foster human-AI symbiosis. Rather than aiming to supplant human educators, the true conceptual goal of AIED is to automate routine cognitive and administrative tasks, thereby liberating teachers to focus on higher-order pedagogical responsibilities, such as emotional mentorship, moral guidance, and the facilitation of complex, collaborative problem-solving. Thus, AIED is fundamentally defined not just by the integration of advanced algorithms, but by its profound capacity to amplify human intelligence and democratize access to high-quality, individualized learning experiences.

2. Core Application Scenarios of AI in Education

2.1 Intelligent Tutoring Systems and Personalized Learning

Intelligent Tutoring Systems (ITS) represent one of the most prominent applications of AI in education today. Generative AI-based teaching systems can break through the rigid logic of traditional question banks, providing students with interactive experiences akin to those with a human tutor. For instance, these systems can dynamically generate personalized learning paths and adaptively difficult questions based on students' real-time performance in assessments. Empirical studies indicate that, within immersive learning experiences, students using AI-assisted learning significantly outperform traditional control groups in exam scores and complex problem-solving abilities [3]. Furthermore, AI-driven intelligent assessment enables automated and precise evaluation of subjective questions, oral expression, and even thought processes.

To fully comprehend the revolutionary impact of Generative AI within Intelligent Tutoring Systems (ITS), it is essential to examine the architectural shift from traditional rule-based environments to dynamic, probabilistic cognitive modeling. Historically, conventional ITS relied heavily on predefined decision trees and static cognitive architectures (such as ACT-R). These legacy systems could only guide students down pre-programmed pathways; if a student exhibited an unconventional misconception that the developers had not explicitly anticipated, the system would fail to provide relevant remediation. In stark contrast, modern GenAI-driven ITS leverages the vast semantic understanding of Large Language Models (LLMs) combined with dynamic knowledge graphs. This integration allows the system to interpret semantic ambiguities, decipher the root cause of a student's unique misunderstanding, and autonomously synthesize bespoke explanatory content in real-time.

At the core of this hyper-personalized learning experience is the implementation of advanced Deep Knowledge Tracing (DKT). Unlike rudimentary scoring algorithms that merely tabulate correct and incorrect responses, DKT utilizes Recurrent Neural Networks (RNNs) and Long Short-Term Memory (LSTM) architectures to model a student’s knowledge state as a continuously evolving, high-dimensional vector. The AI continuously ingests granular behavioral data—including response latency, the specific sequence of interface interactions, revision histories, and even cursor hesitations. By mapping these micro-behaviors against a comprehensive ontological map of the academic domain, the system can predict with remarkable accuracy which specific prerequisite concepts the student has failed to master. Consequently, the ITS can dynamically restructure the curriculum, seamlessly injecting targeted micro-lessons exactly when the cognitive deficit is detected, thereby preventing the compounding of foundational errors.

Furthermore, the pedagogical strategy employed by these advanced AI tutors fundamentally shifts from direct instruction to sophisticated "epistemological scaffolding." Grounded in Lev Vygotsky’s educational theory of the Zone of Proximal Development (ZPD), the AI constantly calibrates the difficulty of tasks to keep the learner in a state of optimal flow—neither bored by excessive simplicity nor paralyzed by overwhelming complexity. When a student encounters a cognitive block, the GenAI does not simply provide the correct answer. Instead, it engages in a Socratic dialogue. Through a series of progressively narrowed, highly contextualized prompts, the AI guides the student to independently connect the dots. For example, in a complex physics problem, the AI might ask, "Consider the law of conservation of energy; what happens to the kinetic energy as the pendulum reaches its highest point?" This method actively cultivates higher-order critical thinking and metacognitive skills, ensuring that students internalize the problem-solving methodology rather than merely memorizing facts.

Beyond cognitive mapping, the frontier of personalized learning is being profoundly reshaped by the integration of Affective Computing and Multimodal Learning Analytics (MMLA). Learning is inherently an emotional and psychological process, and modern ITS are increasingly equipped to recognize and respond to the affective states of the learner. Utilizing computer vision via webcams and natural language processing of vocal intonations, the system can detect micro-expressions associated with frustration, boredom, or cognitive overload. If the AI detects that a student is exhibiting signs of severe frustration—such as a sustained furrowed brow, rapid guessing, or exasperated sighs—it can autonomously pivot its instructional strategy. It might temporarily lower the cognitive load, introduce a visually engaging simulation, or employ empathetic conversational agents to offer encouragement and normalize the struggle of learning.

Finally, the capability of AI-driven ITS to conduct automated, precise evaluations of complex, open-ended tasks represents a monumental leap in formative assessment. Traditionally, automated grading was strictly confined to multiple-choice or fill-in-the-blank formats. Today, AI can evaluate the syntactic elegance and logical coherence of a student's computer programming code, providing line-by-line debugging mentorship. In mathematics, computer algebra systems coupled with machine learning can evaluate the procedural validity of a student's step-by-step derivations, identifying exactly where a logical fallacy occurred even if multiple valid methods exist to solve the problem. In the humanities, natural language processing algorithms can assess argumentative essays not just for grammatical correctness, but for thematic consistency, the strength of evidence provided, and the logical flow of the thesis. This capability ensures that formative assessment becomes a continuous, invisible, and highly constructive component of the daily learning loop, rather than a high-stakes, anxiety-inducing endpoint.

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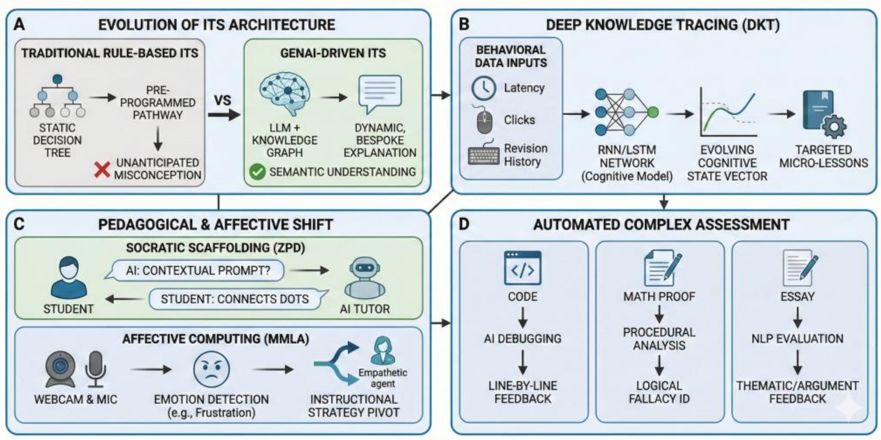

Figure 1. Generative AI-Driven Intelligent Tutoring Systems (ITS): Architecture, Tracing, Pedagogy & Assessment

2.2 Popularization of Edge AI Educational Hardware

With the decentralization of computing power, the application of Edge AI technology in educational hardware is becoming increasingly widespread, marking a profound paradigm shift from cloud-dependent architectures to localized processing. Historically, AI-driven educational tools required constant, high-bandwidth internet connections to transmit audio, video, and behavioral data to remote servers for algorithmic analysis. Today, the integration of miniature, highly efficient Neural Processing Units (NPUs) directly into the silicon of consumer and classroom devices has fundamentally revolutionized this dynamic.

Between 2024 and 2025, the market size of consumer-facing (C-end) and business-facing (B-end) hardware—represented by AI learning devices equipped with specialized NPUs, smart translation pens, and intelligent interactive displays—achieved a compound annual growth rate of over 20% [4]. These specialized NPUs are purpose-built to execute the complex matrix multiplications required by machine learning models at a fraction of the power consumption of traditional processors. Consequently, these Edge AI hardware solutions do not rely heavily on cloud computing power; they can provide real-time speech recognition, gaze tracking, and error analysis in low-latency offline states.

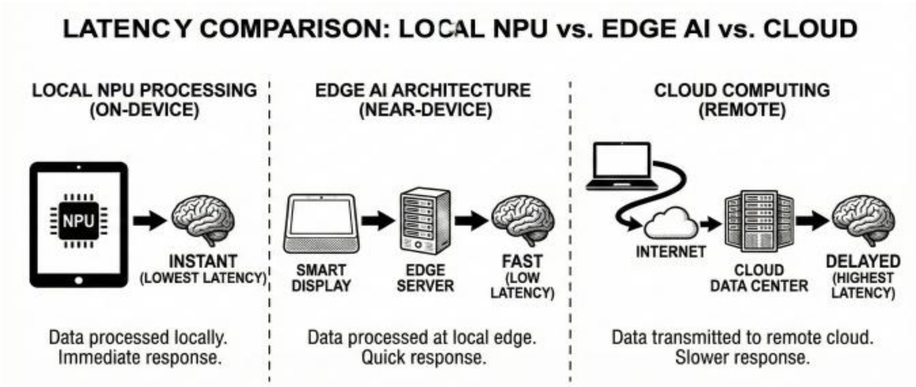

Figure 2. Schematic comparison of latency in educational AI architectures, highlighting the speed advantage of local and edge processing over cloud computing.

The operational advantages of this localized computation are multifaceted. For instance, in language acquisition applications, edge-based acoustic models can evaluate a student's pronunciation, phonetics, and prosody in mere milliseconds. This provides instantaneous corrective feedback that mimics natural human tutoring without the disruptive lag typically associated with cloud latency. Similarly, smart translation pens utilize edge-based Optical Character Recognition (OCR) alongside lightweight, localized large language models (LLMs) to instantly decode complex texts and mathematical formulas, functioning effectively even in environments entirely devoid of Wi-Fi.

Furthermore, the transition to Edge AI addresses one of the most pressing socio-technical concerns in modern educational technology: data privacy and security. By processing sensitive biometric and behavioral metrics—such as voice recordings, facial micro-expressions, and visual focus patterns—strictly on the local device, Edge AI inherently complies with stringent global data protection regulations concerning minors. Because the raw data never leaves the hardware, the risk of unauthorized access or data breaches is drastically mitigated.

Ultimately, this significantly expands the physical scope of AI-enabled education, extending it beyond information-based classrooms to ubiquitous learning (U-learning) scenarios, including home and outdoor environments. This architectural shift plays a crucial role in democratizing access to advanced educational resources. Students in rural or underserved areas with limited, unstable, or entirely absent broadband infrastructure can now experience the same adaptive, highly responsive AI tutoring as their urban counterparts. Whether a student is navigating a field trip, commuting on a bus, or studying in a remote village, edge-powered educational hardware ensures that continuous, high-quality, and personalized learning remains entirely uninterrupted.

2.3Teacher Empowerment and Intelligent Management

AI is endowing teachers with new roles and missions. Generative AI facilitates intelligent lesson preparation, automatically generating teaching plans, multimedia courseware, and formative assessment tools, thereby freeing teachers from repetitive administrative tasks and enabling them to devote more energy to student emotional support and creative instructional design [5]. At the level of campus management, by establishing a data-intelligent governance framework involving multiple stakeholders, school administrators can leverage AI to conduct multidimensional big-data predictive analyses on campus safety, student mental health trends, and the allocation of teaching resources.

The transformative potential of AI in teacher empowerment and intelligent management extends far beyond these initial applications. The shift from administrative burdens to pedagogical leadership is crucial. AI-powered tools can not only generate lesson plans but also analyze student performance data to suggest personalized learning pathways, identify at-risk students earlier, and recommend targeted interventions. This moves teachers from a "one-size-fits-all" approach to a more nuanced and effective instructional model. Furthermore, AI can analyze teaching practices themselves, providing teachers with feedback on their questioning techniques, classroom management strategies, and overall effectiveness, fostering continuous professional development. This data-driven feedback loop can be invaluable for both new and experienced educators, offering insights that were previously unavailable or difficult to obtain.

On the campus management front, the predictive capabilities of AI can be further leveraged. Beyond analyzing trends, AI can help proactively address potential issues. For example, by analyzing student attendance records, academic performance, and social media activity (with appropriate privacy safeguards), AI could identify students who may be struggling with mental health issues or are at risk of dropping out, allowing schools to intervene early and provide necessary support. Furthermore, AI can optimize resource allocation in more sophisticated ways. It can analyze patterns in facility usage, energy consumption, and even student course selections to suggest more efficient scheduling, identify areas for cost savings, and ensure that resources are directed where they are needed most. This data-driven approach can lead to more equitable and effective resource distribution across the campus.

Moreover, AI can facilitate better communication and collaboration among stakeholders. AI-powered chatbots could handle routine inquiries from parents and students, freeing up staff time for more complex issues. AI can also analyze feedback from students, parents, and teachers to identify areas for improvement in school policies and programs. This can lead to a more responsive and inclusive school community. Ultimately, the goal of AI in education is not to replace teachers or administrators but to augment their capabilities, enabling them to make more informed decisions, provide more personalized support to students, and create more effective and equitable learning environments. The successful integration of AI in education will require careful planning, ethical considerations, and ongoing professional development to ensure that these powerful tools are used responsibly and effectively.

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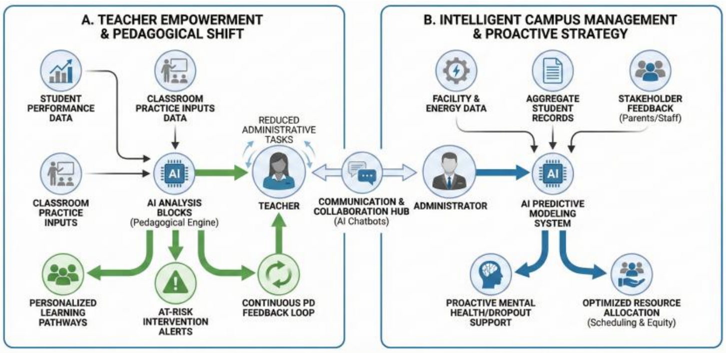

Figure 3. AI-Augmented Educational Ecosystem: Empowerment & Intelligent Management

3. Synergy of AI and Human Intelligence

The deepening integration of technology has not diminished the role of human teachers; instead, it has fostered a new, more profound and humane division of labor within the educational ecosystem. Artificial intelligence, with its powerful data processing and pattern recognition capabilities, has taken on standardized and repetitive cognitive tasks in the educational process. As a "universal knowledge transmitter," it provides precise knowledge services across temporal and spatial boundaries; as a "learning analytics specialist," it offers objective, dynamic, and evidence-based insights for instructional decision-making through continuous tracking of learning behaviors. This technological empowerment liberates teachers from heavy, mechanical workloads, allowing them to devote more energy to humanistic care and creative educational activities that machines cannot replicate.

The core value of human teachers lies precisely in their irreplaceable "human dimension." As "learning facilitators," they are not merely transmitters of knowledge but also inspirers of thinking methods and igniters of learning motivation. As "psychological counselors," they help students build healthy self-awareness and emotional regulation skills through empathy and trust. As "instructional decision-makers," they integrate objective data provided by AI with their own educational wisdom to make professional judgments imbued with values in complex situations.[6] This "AI+HI" collaboration is, in essence, an organic fusion of instrumental and value rationality.

Within the "Five-Education Integration" framework for holistic student development, this collaborative model demonstrates strong integrative potential. Intelligent technology supports moral education through case simulations, adaptive learning pathways for intellectual education, sports performance data analysis for physical education, digital creative spaces for aesthetic education, and connections to social practice resources for labor education. In this process, teachers act as value guides, process supervisors, and outcome evaluators, ensuring that technological applications consistently serve the fundamental goal of "holistic human development." Ultimately, this deeply integrated educational paradigm is systematically cultivating future citizens equipped with digital literacy, critical thinking, innovative mindsets, and a sense of social responsibility.

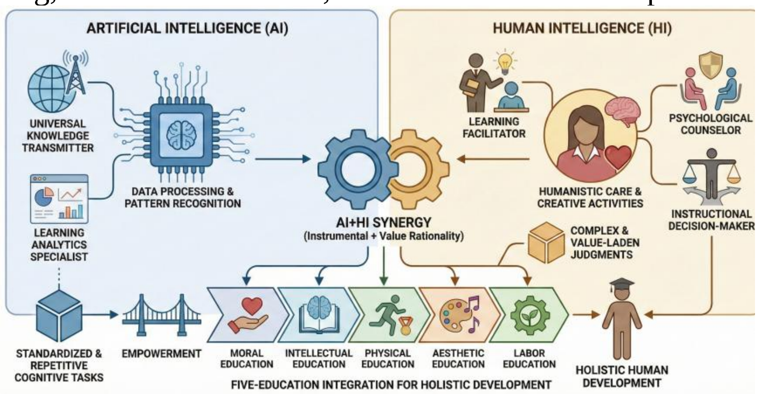

Figure 4. AI & Human Intelligence Synergy in Education

4. Ethical Challenges and AI Governance

4.1 Algorithmic Bias and Filter Bubbles

When discussing the ethical dilemmas of applying artificial intelligence in education, it is crucial to first confront the systemic inequity caused by algorithmic bias. Further analysis reveals that algorithmic bias is not merely a coding error but a digital reflection of historical social inequalities in human society. During the collection of educational big data and the training of deep learning models, algorithms inevitably absorb the socio-economic attributes hidden behind historical academic performance and behavioral logs. For example, when AI is used to predict students' dropout risks or for academic streaming, models often implicitly rely on proxy variables such as home zip codes or past disciplinary records. This mechanism leads students from low-income families or marginalized communities to be disproportionately classified as "high-risk" by the system, resulting in their overrepresentation in basic remedial courses rather than challenging elite programs. This phenomenon, known as "algorithmic redlining," essentially institutionalizes the consolidation of educational resources across social strata under the guise of "objective, data-driven" science. Additionally, in natural language processing (NLP) and automated essay scoring systems, models are predominantly trained on standardized written corpora. This often causes them to unfairly downgrade texts from students in dialect regions, ethnic minorities, or English as a second language (ESL) learners, as they fail to recognize their unique syntactic structures or colloquial variations, thereby exacerbating the marginalization risks in educational assessment.

Beyond the assessment inequities caused by algorithmic bias, excessive reliance on AI-driven adaptive learning platforms has triggered another, more insidious and far-reaching educational crisis: the "filter bubbles" and "epistemic enclosure" in knowledge acquisition. Traditional educational environments emphasize unified curriculum standards, serendipitous discoveries in physical libraries, and highly heterogeneous classroom interactions—elements that compel students to step outside their cognitive comfort zones and engage with interdisciplinary peripheral knowledge and challenging opposing viewpoints. However, the underlying logic of modern commercialized educational AI recommendation engines often prioritizes "maximizing learning efficiency" and "user engagement." To sustain students' activity on the platform, algorithms continuously monitor their clickstreams, dwell time, micro-expressions, and answer accuracy rates. Once the system detects cognitive resistance, anxiety, or a tendency to abandon tasks when students encounter complex texts or heterogeneous viewpoints, the recommendation algorithm automatically filters out such materials deemed as "high cognitive friction" in future learning pathways.

Over time, this extreme "hyper-personalization" of the learning experience erects an invisible digital barrier around students. They become tightly wrapped in an "echo chamber" tailored by algorithms, where the system only pushes homogeneous content that aligns with their existing cognitive levels and interest preferences. In such an environment of absolute accommodation, the foundational cornerstone for cultivating higher-order critical thinking—the ability to confront contradictory information, tolerate cognitive ambiguity, and integrate opposing perspectives—inevitably atrophies due to prolonged "cognitive deprivation."

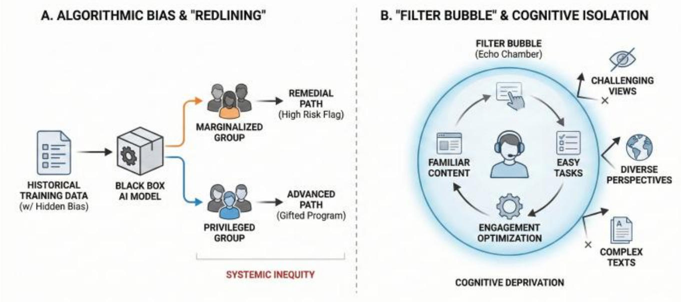

Figure 5. Mechanisms of Algorithmic Bias & Filter Bubbles in Educational AI

From a macro-sociological perspective, the "filter bubble" effect in the education sector poses a serious long-term threat to social cohesion and the future collective discourse system. One of the

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fundamental social functions of public education is to provide a shared knowledge base, moral consensus, and cultural context for the younger generation from diverse backgrounds. If every student experiences completely isolated, tailor-made, and fundamentally distinct cognitive pathways through artificial intelligence agents, the same generation will gradually lose the shared intellectual common ground needed for discussing complex social issues and engaging in cross-boundary collaboration. The classroom will cease to be a public sphere for the collision of ideas and instead devolve into isolated islands of information consumption, where individuals engage with screens in solitude. Even more concerning, when educational digital infrastructure is monopolized by a few leading technology companies, and in the absence of transparent regulatory oversight and opaque "black box" operations, platform recommendation algorithms are highly susceptible to commercial interests or specific ideological biases, leading to imperceptible manipulation of the cognitive development of minors.

Therefore, to break this technological-induced cognitive confinement and the entrenchment of biases, the architectural design of educational AI in the future must undergo a fundamental paradigm shift from a purely "efficiency-driven" approach to one of "cognitive expansion." At the algorithmic engineering level, developers must mandatorily incorporate a dynamic balancing mechanism of "exploration versus exploitation." The system should not merely "exploit" students' known preferences but proactively "explore" their untapped potential. It should be designed to intentionally inject "planned serendipity" into students' learning pathways, timely introducing interdisciplinary materials and cognitively challenging tasks to break the monopoly of homogeneous information. Additionally, educational administrators and decision-makers urgently need to establish an agile algorithm accountability and ethical review mechanism. This will ensure the representativeness of datasets used to train algorithmic models and preserve the "human-in-the-loop" authority for teachers in critical educational assessment processes. Only by ensuring that technology not only enhances the efficiency of mastering standardized knowledge but also safeguards the breadth of students' intellectual horizons and their freedom to explore the unknown, can artificial intelligence transcend the limitations of "instrumental rationality" and truly become a wise partner in promoting holistic human development.

4.2 Building Trustworthy AI Ethics in Education

Defining the boundaries of AI applications in education is a current priority in governance. Schools, technology companies, and regulatory agencies are collaborating to establish clear ethical guidelines for AI in education[9]. These include: requiring AI algorithms to maintain transparency and explainability in core educational decisions (such as enrollment evaluations); formulating strict laws to protect student data privacy; and promoting "AI literacy education" for teachers and students, guiding them not to blindly trust AI and to maintain critical and independent thinking skills[8].

5. Conclusion and Future Outlook

5.1 Conclusion: Paradigm Shift from Peripheral Auxiliary to Core Infrastructure

The year 2025 marks the "singularity" where the application of AI technology in education surpasses preliminary exploration, officially evolving from a peripheral "auxiliary tool" into the "core infrastructure" that underpins modern educational systems. Through boundless intelligent teaching agents and ubiquitous computing power localized on devices, high-quality personalized learning resources can bridge the urban-rural digital divide. This provides a historic opportunity for the mass realization of the "personalized learning" ideal, a goal pursued throughout the history of human education[10].

5.2 Challenges: Socio-Ethical Considerations Beyond Engineering Logic

However, the comprehensive implementation of AI educational technology is by no means purely a computer software engineering issue; it is a highly complex sociological and educational ethical topic. Future research and teaching practices should place greater emphasis on "Educational Suitability." The core challenge currently faced is how to promote the profound "Value Alignment" between fundamental human values and large AI models. Systems must embed anti-bias mechanisms during the algorithm design phase, protect student data privacy, and remain highly vigilant against

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technological over-intervention that "deprives" or "substitutes" students' critical thinking and independent exploration capabilities[11].

5.3 Future Outlook: Building a Synergistic AI+HI Educational Ecosystem

Looking ahead, the digital-intelligent transformation of the educational system urgently requires the establishment of an agile governance framework co-participated by governments, tech enterprises, schools, and society. Building on this, future educational paradigms will completely abandon the zero-sum game of "machines replacing humans" and move towards a deeply synergistic and symbiotic model of "Artificial Intelligence + Human Intelligence (AI+HI)." AI will take over the precise transmission of massive knowledge, while human teachers will return their core focus to emotional care and moral guidance. Ultimately, our education will be dedicated to cultivating high-caliber, versatile talents equipped with solid AI literacy and interdisciplinary innovative capabilities.

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