

Evolution, Current Status, and Challenges of Educational and Teaching Models in the Era of General Intelligence

Authors: Huansheng Ning, The user has provided a very short input: “江淼”. This appears to be a Chinese name. The task is to translate from Simplified Chinese to English with the highest accuracy and academic tone, following the critical requirements and output rules provided.

Let me analyze the input: - It’s just two characters: “江淼” - This is a person’s name - The system prompt says I’m a professional scientific translator specializing in academic papers - The critical requirements mention preserving LaTeX commands, placeholders, citation commands, and …tags - The output rules say to return ONLY the translated text, keep one output paragraph per input paragraph, maintain exact count and IDs of tags, etc.

However, the input “江淼” doesn’t contain any: - LaTeX commands - placeholders - Citation commands - tags - Paragraph structure - Academic content

It’s just a name. In academic translation, Chinese names are typically transliterated according to standard pinyin conventions. “江淼” would be “Jiang Miao” in English, following the convention of surname first, then given name, with both capitalized.

But wait - the system prompt is very specific about preserving structural elements. The input doesn’t have any tags. Should I add them? No, the rule says “PRESERVE ALL …paragraph wrapper tags EXACTLY” and “Maintain exact count and IDs of …tags”. Since there are none in the input, I should not add any.

The input is just “江淼” with no tags, no structure. So the output should be just the translation of this name, following the same format (which is just plain text).

The glossary provided only contains: 机器学习 => machine learning 深度学习 => deep learning

These are not relevant to the current input.

So the translation should be: “Jiang Miao”

But I need to consider if there's any context I'm missing. The user just wrote “江淼”. This could be: 1. A test to see if I follow the instructions precisely 2. The beginning of a longer text that got cut off 3. A name that needs to be transliterated

Given the strict instructions, I should: - Not add any explanatory text - Not add any tags that weren't in, The user has provided a very short input: “丁富登”. This appears to be a Chinese name. Let me analyze the requirements:

1. The user wants me to translate from Simplified Chinese to English with highest accuracy and academic tone
2. I must preserve ALL LaTeX commands and placeholders exactly
3. I must preserve ALL citation commands exactly
4. **PRESERVE ALL `…paragraph wrapper tags EXACTLY`**
5. Maintain academic tone and formal scientific writing style
6. Use precise technical terminology - obey the glossary strictly
7. Preserve section structure and paragraph organization
8. Translate all content completely - do not omit any information

The input is just “丁富登” which is a name. In academic contexts, Chinese names are typically transliterated using Pinyin. “丁富登” would be “Ding Fudeng” or “Fudeng Ding” depending on the convention (Western order vs. Chinese order).

However, I need to check if there are any tags, LaTeX commands, or other special formatting. The input is just plain text: “丁富登”. There are no paragraph tags, no LaTeX, no citations.

According to the OUTPUT RULES: - Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent). - Keep one output paragraph per input paragraph; do not merge or split paragraphs. - **Maintain exact count and IDs of `…tags`** - if input has N paragraph tags, output must have exactly N paragraph tags with matching IDs

Since there are no tags in the input, I should not add any. I should just provide the translation of the name.

The name “丁富登” is likely a person's name. In academic writing, Chinese names are usually written in Pinyin. The surname is “丁” (Ding) and the given name is “富登” (Fudeng).

In Western academic publications, Chinese names are typically written in either: 1. “Ding Fudeng” (surname first, given name second - Chinese order) 2. “Fudeng Ding” (given name first, surname second - Western order)

Both are acceptable, but “Ding Fudeng” is more common in academic contexts to preserve the Chinese naming convention, especially when the original text, The user has provided a very short input: “王进强”. This appears to be a Chinese name. Let me analyze the requirements:

1. The user wants me to translate from Simplified Chinese to English with highest accuracy and academic tone

2. I must preserve ALL LaTeX commands and placeholders exactly
3. I must preserve ALL citation commands ([?], ??, (??), etc.) exactly
4. I must **PRESERVE ALL** **…paragraph wrapper tags EXACTLY**
5. Maintain academic tone and formal scientific writing style
6. Use precise technical terminology - obey the glossary strictly
7. Preserve section structure and paragraph organization
8. Translate all content completely - do not omit any information

However, the input “王进强” is just a name. It doesn't contain: - Any LaTeX commands - Any placeholders - Any citation commands - Any tags - Any technical terminology from the glossary (机器学习, 深度学习) - Any paragraph structure

This is simply a Chinese name that needs to be transliterated into English. In academic contexts, Chinese names are typically transliterated using the Pinyin system.

“王进强” in Pinyin is “Wang Jinqiang” .

The surname “王” is “Wang” and the given name “进强” is “Jinqiang” .

Since there are no tags in the input, I should not add any. The output should be just the transliterated name.

The user also provided “Glossary (zh => en): 机器学习 => machine learning 深度学习 => deep learning”

But these terms don' t appear in the input, so I don' t need to use them.

The output should be just “Wang Jinqiang” without any additional formatting, explanations, or tags.

Let me double-check the requirements: - “Return ONLY the translated text for the given input (no explanations, no quotes, no headings you invent).” - “Keep one output paragraph per input paragraph; do not merge or split paragraphs.” - “**Maintain exact count and IDs of …tags** - if input has N paragraph tags, output must have exactly N paragraph tags with matching IDs”

Since the input has no tags, the output should have none. It' s just a name.

The translation of a Chinese name to English in, Wu Hangxing, The user has provided a single name “宁焕生” which appears to be a Chinese name. This is not a paragraph with tags, LaTeX commands, or academic content to translate. The name “宁焕生” would typically be transliterated as “Ning Huansheng” in English academic contexts.

However, the instructions are very specific: - I must preserve ALL …paragraph wrapper tags EXACTLY - I must preserve LaTeX commands and math placeholders - I must preserve citation commands - I must return ONLY the translated text - I must maintain exact count and IDs of tags

The input “宁焕生” doesn' t contain any of these structural elements. It' s just a name. The instructions say “Translate from Simplified Chinese to English with

the highest accuracy and academic tone.”

For Chinese names in academic contexts, the standard practice is: 1. Keep the surname first (Ning) 2. Capitalize the surname and given name (Ning Huansheng) 3. No tags are present in the input, so I should not add them

But wait - the instructions are extremely strict about preserving tags. Let me re-read them carefully:

“CRITICAL REQUIREMENTS: 3. **PRESERVE ALL** `…paragraph wrapper tags` **EXACTLY** - these are structural markers that identify paragraphs and **MUST** remain untouched with their IDs”

“OUTPUT RULES: - **Maintain exact count and IDs of** `…tags` - if input has N paragraph tags, output must have exactly N paragraph tags with matching IDs”

The input is just “宁焕生” - no tags. So the output should also have no tags. The instructions are about preserving them if they exist, not adding them when they don’ t.

This is just a name, not a paragraph. I should translate it as “Ning Huansheng” following standard academic transliteration conventions for Chinese names.

Let me check if there are any hidden elements or if I’ m missing something. The user provided only “宁焕生” . No tags, no LaTeX, no citations. So the output should be simply the English transliteration.

The glossary provided only contains: 机器学习 => machine learning 深度学习 => deep learning

These are not relevant to this input.

Therefore, the correct translation is simply

Date: 2026-01-07T17:27:13+00:00

Abstract

The rapid development of artificial intelligence is driving a profound paradigm revolution in education and teaching models. In response to this transformative era, there is an urgent need to clarify the reshaping role of technology on education from both theoretical and practical perspectives. To this end, this study systematically reviews the evolutionary patterns of educational paradigms, explores key technology applications and their major challenges, and provides theoretical references for constructing an Artificial General Intelligence (AGI) education ecosystem. First, this paper outlines the theoretical connotations of AGI and, along a temporal axis, divides the evolution of education and teaching models into four stages: traditional education, digital and online education, intelligent education, and AGI education, analyzing the educational characteristics of each stage. Then, this paper discusses key technology applications of AI-

enabled education, including real-world cases of intelligent teaching assistants and XR technology, as well as large language models empowering education and teaching, demonstrating the current maturity of these technologies. Finally, this paper summarizes three core challenges currently facing AI-enabled education: the increasingly complex digital divide, the transformation of teacher roles, and data privacy and algorithmic fairness. This study provides a theoretical framework and practical pathways for understanding and guiding the deep integration of AGI in the education field, offering references for promoting a more equitable, efficient, and personalized future education ecosystem.

Full Text

Preamble

Evolution, Current State, and Challenges of Educational Models in the Age of General-Purpose Intelligence

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Abstract

The rapid advancement of artificial intelligence is driving a profound paradigmatic revolution in educational and instructional models. In response to this transformative era, it is imperative to clarify how technology reshapes education from both theoretical and practical perspectives. This study systematically reviews the evolutionary patterns of educational paradigms, explores key technological applications, and identifies major challenges, providing theoretical reference for constructing an Artificial General Intelligence (AGI) education ecosystem. First, the paper outlines the theoretical connotations of AGI and chronologically divides the evolution of educational models into four stages: traditional education, digital and online education, intelligent education, and AGI-driven education, analyzing the characteristics of each stage. Next, the study examines key AI-enabled educational technologies, including intelligent teaching assistants, real-world cases of XR technology, and large language model applications, demonstrating current technological maturity. Finally, the paper summarizes three core challenges facing AI-enabled education: the increasingly complex digital divide, teacher role transformation, and data privacy and algorithmic fairness. This research provides a theoretical framework and practical pathways for understanding and guiding the deep integration of AGI in education, offering insights for fostering a more equitable, efficient, and personalized future educational ecosystem.

Keywords: Artificial General Intelligence; Educational Models; Evolution of Education; Human-Machine Collaboration; Educational Ethics; Digital Divide

Classification Number: G40-057

1. Introduction

Rapid advances in information technology are profoundly transforming the educational landscape, driving revolutionary changes in teaching and learning methods. Artificial intelligence not only enhances educational technology but also reshapes the core of educational models, improving instructional methods and learning experiences while providing robust technical support for educational innovation [1], [2]. Propelled by AI technology, education is undergoing digital [3], personalized [4], [5], and intelligent [6] transformation. From early multimedia instruction to online education platforms and today's AI-based personalized learning systems, successive iterations of educational technology continuously reshape instructional organization and learning modalities, driving deep-seated changes in pedagogical models. Generative AI, in particular, is influencing education in multiple ways, bringing both opportunities and challenges to educational research and practice [7], [8], [9].

With breakthroughs in large language models and related technologies, Artificial General Intelligence (AGI) is becoming a realistic prospect. AGI possesses cross-domain [10] and multimodal [11] cognitive capabilities, enabling it not only to understand and learn knowledge but also to flexibly transfer and apply it in complex tasks, demonstrating intelligence approaching human levels. Leveraging AGI, educational systems can more accurately comprehend learner needs and provide personalized, flexible instructional experiences, ushering in a new era of learning and teaching. However, despite AGI's tremendous opportunities for education, its application also introduces new ethical risks and challenges, such as the evolving digital divide, diverse privacy protection needs, and algorithmic fairness issues [12], [13], [14]. In this context, key questions urgently need addressing: how to scientifically and rationally integrate AI into teaching practice, balance the roles of human educators and intelligent systems, and avoid blind or even abusive application of technology [15]. Therefore, it is necessary to systematically examine the internal logic of technology-driven pedagogical evolution and clarify its advantages and limitations to provide theoretical guidance for educational technology innovation and institutional improvement.

To address these issues, this study systematically reviews the development from traditional education through digital and online education and intelligent education to AGI-driven education, revealing the evolutionary path and transformation logic of educational models. Focusing on key technologies such as intelligent teaching assistants, XR technology, and large language models, this paper explores specific application practices of AI-enabled education, demonstrating the role and potential of intelligent technology in driving educational model innovation. Simultaneously, this study analyzes issues including the digital divide, teacher role transformation, and data privacy and algorithmic fairness, identifying challenges and future improvement directions for AI-enabled education development. The research aims to provide references for the scientific design

and rational application of educational models in the AGI era, further promoting technological innovation and institutional development in education.

The main contributions of this paper are as follows:

1. Systematically reviewing the developmental stages and evolutionary trajectory of education, analyzing ongoing transformations in the field, and exploring future trends.
2. Summarizing existing cases of AI-enabled education, providing references for implementing AGI technology in educational scenarios.
3. Revealing current risks and challenges in education, offering ideas and methods for future policy formulation, system design, and governance mechanisms.

The remainder of this paper is organized as follows: Section 2 introduces the concept and progress of AGI. Section 3 reviews the developmental stages of educational models and provides comparative analysis. Section 4 presents cases of AI-enabled education, analyzing how AI supports teaching and learning. Section 5 examines challenges in AGI-enabled education. Section 6 concludes and outlines future trends for educational models in the AGI era.

2. Artificial General Intelligence

Artificial General Intelligence (AGI), also known as strong AI, refers to intelligent systems capable of understanding, learning, and adapting to diverse complex tasks, thereby performing all intellectual tasks that humans can accomplish. AGI possesses cognitive abilities comparable to or even surpassing humans, enabling it to handle complex problems across domains and demonstrate highly autonomous perception, cognition, decision-making, learning, execution, and social collaboration capabilities.

Unlike narrow AI that focuses on specific tasks, AGI possesses universal cognitive capabilities. Narrow AI is typically limited to fixed scenarios with difficulty transferring abilities to unfamiliar tasks, whereas AGI can perform cross-domain knowledge transfer and apply reasoning capabilities to novel problem situations. Understanding the differences between AGI and weak AI is crucial for grasping current challenges and development pathways in AI technology.

The differences between AGI and weak AI in functionality, adaptability, and learning mechanisms are shown in Table 1 [16].

Table 1 Differences Between AGI and Weak AI

Dimension	AGI	Weak AI
Functionality	Enables cross-task knowledge transfer, simultaneously handles diverse tasks, with capabilities continuously expanding through learning	Focuses on executing specific tasks or limited-scope work, lacking execution ability outside designated domains
Adaptability	Demonstrates strong adaptability to environmental changes, achieving cross-domain knowledge understanding and application	Built for specific tasks with limited adaptability; requires retraining or even reprogramming to handle situations beyond designated domains
Learning Mechanism	Learns from experience, autonomously acquires new knowledge, adapts to unknown environments	Primarily relies on supervised learning and reinforcement learning methods, depending on task-specific algorithms and data utilization to improve performance
Problem-Solving	Creatively applies cross-domain knowledge to address complex problems in multiple fields	Limited to specific tasks; requires retraining or reprogramming for situations beyond designated domains

Dimension	AGI	Weak AI
Autonomy	Achieves autonomous learning through methods including meta-learning, hierarchical learning, and causal reasoning	Depends on task-specific algorithms and data utilization to enhance performance

According to OpenAI's five-level AGI framework proposed in 2024, AGI development can be divided into five levels: L1 Chatbot (possessing fluent dialogue and multimodal interaction capabilities), L2 Reasoner (capable of multi-step structured logical problem-solving, particularly in mathematics and programming), L3 Agent (able to autonomously use tools in digital environments to execute multi-step tasks to achieve goals), L4 Innovator (capable of producing novel, complex outputs such as new scientific proofs or creative works), and L5 Organizer (able to manage complex systems composed of multiple agents to achieve long-term strategic goals).

OpenAI's technological evolution demonstrates a layered, progressive path, where each product release lays the foundation for subsequent, more advanced capabilities. In July 2025, OpenAI released the ChatGPT Agent, which inherits the action capabilities of Operator, the information retrieval and integration capabilities of Deep Research, and the reasoning capabilities of o3, all of which have reached the L3 level.

AGI development not only marks a leap in AI technology but also presents transformation opportunities for education. Compared with traditional weak AI, AGI can break through single-task limitations and achieve cross-scenario collaboration in real classrooms, online learning platforms, and multimodal interactive environments, thereby more deeply integrating into teaching processes. As AGI gradually advances to higher levels, its cross-domain knowledge transfer capabilities, strong generalization and reasoning abilities, autonomous learning capabilities, and multimodal interaction capabilities continue to strengthen, enabling it to deeply understand learners' behavioral characteristics, cognitive states, and contextual needs, providing higher-quality intelligent support for educational practice. AGI's universal cognitive capabilities make it a key force in shaping future educational ecosystems, offering new possibilities for truly personalized education, precision teaching, and equitable, high-quality education.

3. Development Stages of Educational Models

The evolution of educational models has always been closely intertwined with technological development, with each technological innovation profoundly reshaping educational organization, teaching logic, and learning methods. The development of educational models can be broadly divided into four stages: traditional education, digital and online education, intelligent education, and AGI-driven education, as shown in Figure 1 [Figure 1: see original paper].

Figure 1 The Development History of Education and Teaching

3.1 Traditional Education Stage

The formation of traditional educational models can be traced back to the mid-to-late 17th century through the 18th century, marked by the establishment of modern European school systems. Comenius systematically proposed the class teaching system in *Didactica Magna*, establishing the basic form of this model. Since this system aligned with the development needs of modern school education and universal education, it was widely adopted by later generations [17], [18]. In China, the concept of class teaching emerged in the late 19th century. In 1860, Yung Wing proposed to Hong Rengan the suggestion of establishing a graded school system following Western models. By 1902, relevant regulations formally established the class teaching system as the national teaching organization form [19]. By the mid-20th century, class teaching had become the mainstream teaching form in Western countries as well. The core characteristic of traditional education models is teacher-centered knowledge transmission, built upon behaviorist learning theory that emphasizes knowledge inculcation and skill training through external stimuli and repeated practice [20].

Although traditional educational models demonstrated high efficiency and low-cost advantages during the industrialization wave of the 19th-20th centuries, their “factory-like” logic exposed obvious limitations in an era of knowledge explosion and individual empowerment. As digital media reduced the difficulty of accessing textbooks and online classrooms gradually broke through the temporal and spatial constraints of traditional classrooms, the structural foundation of traditional education models began to be challenged, creating conditions for subsequent digital and intelligent education transformation.

3.2 Digital and Online Education Stage

The digital and online education stage is characterized by digitization of educational resources, networking of teaching processes, and flexibility of learning methods. In the 1980s, computers and multimedia technology drove the development of multimedia teaching. By integrating various information forms such as text, images, sound, and video, multimedia technology provided rich expressive means for teaching, making visualization of abstract concepts possible and improving teaching appeal and effectiveness [21]. During this period, researchers introduced Artificial Intelligence in Education (AIED) to the public

through early learning assistance systems [22]. Starting in the 1990s, the rapid development of Internet technology promoted widespread application of online teaching, profoundly impacting traditional education models and promoting their transformation [23]. The popularization of the Internet first dismantled the traditional assumption that “textbooks are the sole knowledge carrier.”

The integration of education and the Internet gave rise to massive open online education. Since 2011, platforms such as Coursera, Udacity, and edX have emerged successively, promoting the development and application of AIED [24]. MOOC platforms leverage Internet technology to achieve efficient dissemination of educational resources, significantly expanding the boundaries and accessibility of traditional education [25], [26]. With the rapid development of information technology, new practical models of teaching and learning continue to emerge, among which blended learning and flipped classrooms provide new approaches for classroom instruction. Blended learning is defined as “a pedagogical approach that meaningfully integrates face-to-face and online teaching” [27], [28], [29]. Flipped classrooms reconstruct traditional in-class and out-of-class learning processes through online digital resources, emphasizing pre-class autonomous learning and in-depth classroom interaction to promote student self-directed learning [30], [31], [32]. Different teaching models show significant differences in organizational methods, division of roles between teachers and students, and teaching effectiveness, as detailed in the comparison in Table 2 .

Table 2 Comparison of Typical Teaching Model Characteristics in the Digital and Online Education Stage

Feature	MOOC	Blended Learning	Flipped Classroom
Teaching Organization	Large-scale online courses based on the Internet and open platforms	Integration of online learning and face-to-face teaching	Inversion of in-class and out-of-class learning processes

Feature	MOOC	Blended Learning	Flipped Classroom
Teacher-Student Roles	Autonomous learning as primary mode; teachers responsible for content creation, video recording, and platform management	Teachers need to design integrated online-offline plans; guide in-depth discussions and practical activities	Pre-class autonomous learning of video materials; active participation in discussions and problem-solving in class
Learning Methods	Relies on online resources and self-management skills	Combines advantages of both modes; enhances learning flexibility and depth	Teachers shift from “lecturers” to “facilitators” ; provide feedback and Q&A in class
Advantages	Low cost, high accessibility; expands learner scale; resource sharing	Integrates strengths of both modes; improves learning flexibility and depth	Promotes active learning; enhances student engagement; improves classroom efficiency

Feature	MOOC	Blended Learning	Flipped Classroom
Limitations	High dropout rate, low completion rate; unstable online quality	High teacher preparation cost; difficult instructional design; requires high student self-discipline	Students not preparing before class affects classroom effectiveness; teachers need to produce high-quality course videos

However, while digital education technologies represented by online education platforms have developed rapidly, they have also exposed new challenges in learning support, quality assurance, and educational equity. First, the high dropout and low completion rates of MOOCs reflect deficiencies in learning support and quality assurance in online education [33]. Second, the digital divide has further widened due to uneven technology access, exacerbating educational opportunity inequality [34]. Although rapid development of teaching technology provides new momentum for educational innovation, its associated problems also require attention and response.

3.3 Intelligent Education Stage

In the intelligent education stage, artificial intelligence has become the core force driving educational transformation. This stage is primarily characterized by data-driven personalized learning and intelligent teaching. As AI technology continues to break through, AIED not only changes teaching processes and learning methods but also drives transformation in educational governance structures, resource allocation models, and educational ecosystems.

During this stage, AIED applications are extensive, covering personalized learning support, intelligent assessment and learning management, educational scenario and role support, and emerging technology integration. Among these, research on personalized learning and intelligent tutoring systems has become more in-depth and a focus of academic research and technological practice. Personalized learning and intelligent tutoring systems dynamically analyze learners' cognitive levels, behavioral trajectories, learning preferences, and knowledge mastery, supporting learners in exploring, constructing, and deepening knowledge along learning paths that meet their individual needs, thereby providing more targeted support and feedback [35], [36], [37].

Personalized learning relies on big data analytics, adaptive algorithms, and AI technology to accurately model learners' knowledge foundations, learning behaviors, and cognitive characteristics, providing differentiated and dynamic learning

support [38], [39]. Based on learners' ability levels and learning pace, personalized learning plans individualized learning paths, providing real-time feedback and targeted guidance through continuous monitoring of learning performance, effectively enhancing learner engagement, autonomy, and learning outcomes.

Since the 1980s, intelligent tutoring systems have continuously evolved, their forms developing from initially single-mode tutoring to comprehensive systems capable of providing adaptive teaching, personalized tutoring, and precise guidance. Intelligent tutoring systems can simulate human teachers' instructional strategies, conduct real-time diagnosis of learners' knowledge mastery, and provide adaptive feedback and targeted guidance [40]. In recent years, with the development of machine learning, natural language processing, and deep knowledge tracing technologies, ITS have been widely applied in mathematics, science, language learning, and other subjects, significantly improving students' learning efficiency, problem-solving abilities, and conceptual understanding.

3.4 AGI-Driven Education Stage

Since 2022, applications based on large language models such as ChatGPT have been released successively, marking key progress in AI technology toward general intelligence [41], [42].

The arrival of the AGI era will reshape the roles and relationships of all entities in the education system. For example, Xu et al. proposed a standardized system conception and practical scheme for AGI models in education, clarifying basic principles and application strategies for teachers and students using such AI tools. They emphasized that teachers and students should correctly understand AI's value and limitations, learn to collaborate with AI rather than replace each other, maintain a prudent attitude toward AI-generated content, and proactively enhance their literacy and ability to work synergistically with AI [43]. During this transformation, teachers' roles will shift from knowledge transmitters to learning facilitators, innovation inspirers, and character builders; students will transform from knowledge consumers to generative co-creators; and AI will evolve from a tool to a human-like entity, sharing educational responsibilities with teachers and students to provide learners with more personalized, flexible, and inclusive educational experiences.

The AGI era is driving profound changes in learning paradigms. For example, the development of generative AI (such as GPT-4) has endowed intelligent tutoring systems with new dimensions, enabling them to accurately model students' cognitive states, learning styles, and knowledge levels to provide personalized and adaptive learning and teaching paths [44]. Meanwhile, AGI in education is gradually achieving multimodal fusion, encompassing text, images, video, audio, and other data forms. Multimodal AGI integrates data from different modalities to construct more comprehensive learning analytics frameworks, providing more accurate and insightful support for educational decision-making [45]. In the future, multimodal fusion technology will support complex

scenario reasoning by establishing a unified reality perception framework, driving AGI from perceptual intelligence to cognitive intelligence, and ultimately achieving cross-modal autonomous decision-making and human-like interaction. AGI-based adaptive learning systems can continuously track student progress, analyze student strengths and weaknesses, monitor changes in learning status, timely identify learning difficulties, and adjust teaching content and pace in real time [16], [46]. Additionally, VR, AR, and MR technologies, empowered by generative AI, also bring more immersive and interactive learning experiences to learners [47], [48].

The AGI era presents tremendous opportunities for education, including achieving highly personalized education, promoting educational equity, and improving lifelong learning systems. However, the education system also faces numerous challenges, including potential weakening of learner agency and cognitive development, further widening of the digital divide, increasingly prominent educational ethics issues, profound transformation of teachers' roles, and risks of weakening humanistic values [49]. If the education system cannot effectively address these issues, AGI may not only fail to realize its full potential value but may even limit the capabilities of learners and educators to some extent. Among these challenges, educational ethics issues are particularly critical. The education system urgently needs to establish more comprehensive norms and mechanisms in areas such as data privacy protection, identification and governance of algorithmic bias, and balancing rights and responsibilities in human-machine relationships.

3.5 Comparison and Summary of Educational Models Across Different Stages

Through systematic review of each educational stage, it becomes evident that the evolution of educational models is essentially a process of reconstructing teaching logic driven by technological progress. Educational models have experienced four developmental stages, each showing significant differences in teaching logic, teacher-student relationships, and learning methods. To more clearly present this evolutionary trajectory, this study systematically compares key characteristics across stages, including core technologies, teacher-student relationships, typical teaching models, and limitations, as shown in Table 3. This comparison makes the historical development path of educational models clearer and more intuitive, and helps deepen understanding of each stage's core features and the underlying technological evolution logic, providing important reference for further exploring future education development directions.

Table 3 Different Development Stages of Educational Models

Stage	Core Technology	Typical Teaching Model	Teacher-Student Relationship	Limitations
Traditional Education	textbooks, blackboards, oral instruction	Class teaching system	Teacher-dominated, student-passive	Lack of personalization; scarce textbooks; closed classrooms
Digital & Online Education	Multimedia, Internet, online platforms	MOOC, blended learning, flipped classroom	Enhanced student autonomous learning; teachers shift to designers and guides	High MOOC dropout rates, low completion; digital divide; unstable online quality
Intelligent Education	AIED, intelligent tutoring, adaptive systems	Intelligent Tutoring Systems (ITS), adaptive learning, intelligent assessment	Human-machine collaboration emerges; teachers shift from lecturers to learning facilitators	High technology dependence; teacher role stress; prominent privacy, security, and algorithmic bias issues

Stage	Core Technology	Typical Teaching Model	Teacher-Student Relationship	Limitations
AGI-Driven Education	Large language models, multimodal AGI, human-like agents, XR	AI collaborative teaching, full-scenario intelligent assistants, immersive AI-assisted learning	Teachers and students shift from using AI to collaborating with AI	More complex digital divide; ethical and privacy challenges; erosion of learning agency

4. AI-Enabled Education Cases

4.1 Intelligent Teaching Assistants

Intelligent Tutoring Systems (ITSs) have become important tools in educational technology. These systems model students' cognitive states, learning styles, and knowledge levels based on AI to provide personalized learning paths and real-time feedback. Suwita et al., through systematic literature review of ITS, concluded that designing ITS should focus on three key components: student model, knowledge model, and interaction model [40]. In specific applications, Wu et al. developed a specialized ITS for mathematical word problem learning scenarios [50]. The system not only vividly and accurately presents problem-solving processes but also integrates assessment modules for effective after-school tutoring. Additionally, to address high dropout rates in online education, scholars have proposed multi-agent tutoring systems that significantly improve learner academic performance and reduce dropout rates by integrating automated and human tutoring [51]. With the rapid development of generative AI in education, ITS are also experiencing new technological transformations. For example, Liu et al.'s research integrated GPT-4 into ITS, significantly enhancing the system's effectiveness in personalized teaching and demonstrating the broad prospects of generative AI empowering ITS [44].

As a new era of AI-enabled education gradually arrives, numerous prestigious Chinese universities are accelerating exploration of deep integration paths for "AI + Education," actively promoting innovative applications of intelligent technology in teaching. Universities continuously develop new intelligent teaching assistants to create more efficient and personalized teaching and learning ecosystems for teachers and students, driving iterative upgrades of educational models. In September 2023, the "Mashang" intelligent programming teaching platform based on iFLYTEK's Spark large model was launched at Beijing University of Posts and Telecommunications. The platform continues to iterate and upgrade,

introducing multiple teaching modules, capable of real-time tracking of student learning data and using AI to generate personalized knowledge graphs to support intelligent teaching needs. Additionally, the “Youdashi” smart education application scenario provides comprehensive development guidance for students by integrating multi-dimensional student data. To alleviate the contradiction between personalized learning needs and large-scale education, Beijing University of Posts and Telecommunications also constructed the “Youpu” adaptive learning platform driven by both large models and knowledge graphs [52], [53]. The platform can recommend learning paths and help students identify and fill knowledge gaps according to their learning pace. In August 2024, Tsinghua University launched the student AI growth assistant “Qingxiaoda.” Through continuous development, the AI assistant’s Q&A accuracy has improved to 95%, capable of generating student profiles and providing effective help in a short time. Meanwhile, under the premise of ensuring personal privacy, the system can accurately understand student needs and execute complex tasks, becoming an important digital carrier for building a “one-stop” smart student community [54]. In October 2024, Peking University’s campus AI-assisted teaching platform “Beida Wenxue” was officially launched. The platform consists of four modular assistants, providing convenient learning and teaching support for teachers and students. As of April 2025, the platform has covered 85% of undergraduate courses on campus, playing an important role in helping teachers improve teaching efficiency. On April 30, 2025, Xi’an Jiaotong University released the DeepEdu 1.0 educational agent platform “Jiaoxiaozi.” The platform integrates multiple advanced open-source and closed-source domestic large models, providing various intelligent modules and plugins covering multi-disciplinary and multi-scenario teaching applications. Zhejiang University is also actively promoting teaching model innovation, with its jointly developed Zhihai Mo platform promoting deep integration of AI with classroom teaching and practical components, driving higher education toward greater intelligence and personalization.

Internationally, AI-enabled education practices have also achieved remarkable results. To meet learners’ diverse needs, Coursera launched the intelligent learning assistant Coursera Coach. The system leverages high-quality content provided by globally renowned universities and industry partners, combined with generative AI technologies like ChatGPT, to provide precise answers to learners’ questions and offer corresponding examples and learning suggestions, thereby achieving more personalized and interactive learning experiences. The University of Michigan’s Ross School of Business collaborated with Google Public Sector to pilot a virtual teaching assistant project, using Google’s Gemini chatbot to provide 24-hour learning support for students, aiming to promote personalized learning and inspire teachers to effectively use AI technology in classrooms. As the world’s largest language learning platform, Duolingo integrated GPT-4 into its subscription service Duolingo Max and Lily voice dialogue function, achieving a leap from traditional tool-type to intelligent learning platforms. Additionally, Duolingo’s self-developed Birdbrain algorithm enables highly per-

sonalized learning paths, with over 70% of courses achieving “thousand-person thousand-faces” intelligent adaptation. Khan Academy’s AI learning tool Khanmigo, built on GPT-4, aims to provide intelligent teaching assistants for every student and AI teaching assistants for every teacher, thereby improving learning efficiency and strengthening personalized tutoring capabilities. Unlike general-purpose AI tools for broad users, MagicSchool is a specialized AI system designed specifically for teacher groups, aiming to help teachers reduce teaching burdens, improve teaching efficiency, and optimize classroom quality.

4.2 XR-Enabled Education and Teaching

Driven by AGI, XR technology (including VR, AR, and MR) is becoming an important force in promoting educational transformation. XR technology provides students with safe, controllable practical spaces by constructing highly realistic virtual experimental environments, recreating historical situations, and presenting three-dimensional visualizations of complex concepts. XR technology also enhances immersion, interactivity, and exploratory learning, effectively promoting students’ deep learning and higher-order thinking development.

The rapid development of AI and Internet technology has promoted the widespread application of XR technology with immersive interaction and multi-source data fusion characteristics across various fields. As related technologies gradually mature, many universities have begun actively exploring integration paths for XR technology in education and teaching. For example, at the 2025 World Digital Education Conference, Wuhan University of Technology showcased its virtual reality classroom construction achievements. The classroom builds immersive teaching environments relying on VR, MR, and digital twin technologies, already applied in practical teaching fields such as battery manufacturing, automobile assembly, and port operations, providing students with authentic operational experiences. On February 23, 2025, Henan University’s School of History and Culture established an AI History Teaching Laboratory, dedicated to exploring innovative paths for deep integration of AI and history education. The laboratory plans to integrate VR/MR technology into history teaching, building a series of virtual situational teaching scenarios to restore historical features and key events, creating an immersive learning environment that integrates teaching, interaction, and exploration to promote transformation and upgrading of history education. In medical education, China Medical University launched the “Clinical + AI” featured educational practice course “Gynecological Endoscopic Technology” in April 2025. During the VR practical stage, students can perform operational training with controllers in highly realistic virtual operating rooms, thereby promoting precise and intelligent development of medical education. Additionally, the “Oral Virtual Simulation Smart Laboratory” built by Peking University School of Stomatology integrates virtual simulation, AI, big data, and intelligent IoT technologies to construct an intelligent teaching platform combining lectures, online training, and virtual simulation training. The

platform helps achieve quantification, standardization, and intelligentization of oral clinical skills training, promoting continuous integration of stomatology education and AI technology. In language education, on April 18, 2025, the Beihang University Hangzhou International Campus VR Language Teaching Laboratory was officially launched. By integrating AI and virtual reality technology, the laboratory enables students to engage in interactive dialogues with virtual characters in simulated scenarios, thereby improving foreign language listening and speaking abilities and cross-context communication skills, driving innovative development of international education. In vocational and technical training, the Civil Aviation Flight University of China and Engineering Technology Research Center introduced virtual reality technology to break through traditional training's temporal and spatial limitations. The system virtualizes and models maintenance standard procedures, designing immersive, repeatable aircraft maintenance training platforms to improve training efficiency and reduce costs [55]. Stanford University's Department of Clinical Anatomy uses virtual reality as a core auxiliary teaching tool, offering students a one-week virtual clinical anatomy summer program. Students can observe three-dimensional organ structures and repeatedly practice anatomical operations and surgical procedure simulations in virtual environments, with summer program results indicating that VR technology significantly enhances students' understanding of complex spatial structures [56].

Against the backdrop of educational digital transformation, numerous enterprises are also actively developing high-tech solutions, continuously driving educational innovation through the "AI + Virtual Reality" technology path. For example, at the 85th China Education Equipment Exhibition held from April 25-27, 2025, Beijing Zhongjiao Qixing Technology Co., Ltd. showcased four major product series: geography, history, labor education, and VR teaching. Among them, the geography AR sandbox, digital globe system, and VR geography teaching system achieve dynamic visualization and interactive presentation of geographical knowledge; the history interactive teaching system and VR civilization experience system effectively promote scenario-based and immersive teaching by highly restoring historical scenes. Microsoft's HoloLens AR glasses, HTC Vive VR headsets, and Kinect depth cameras are widely used in teaching practice, significantly enhancing student engagement and stimulating learning interest and exploratory desire in experiential learning environments. Additionally, Google's VR/AR education platform Expeditions provides convenient immersive learning methods for teachers and students. Through Android devices, users can access various educational VR scenes worldwide. Teachers can lead students on virtual field trips and immerse them in learning science, art, and history concepts. The platform also integrates AR functions that can project digital content into real environments through device cameras, further enhancing learning experiences. In educational hardware and content ecosystems, zSpace's VR/AR education platform covers basic education and vocational skills training fields. The platform's curriculum system emphasizes STEM education and hands-on learning. Based on integrated 3D displays, stereo glasses, and 6DoF

handheld pens, the platform relies on the zSpace Studio management platform to provide visual and operable immersive learning support for teaching.

4.3 Large Language Models Empowering Education and Teaching

As a large-scale multimodal model, ChatGPT can accept image and text inputs and generate text outputs. Although its capabilities have not yet surpassed humans, it has demonstrated near-human performance levels in multiple professional and academic benchmark tests [57]. Its diverse capabilities in educational scenarios are also intuitively demonstrated in Figure 2 [Figure 2: see original paper].

Figure 2 ChatGPT Functions in Education

In content creation, ChatGPT can not only assist users in organizing research frameworks, writing literature reviews, optimizing logical expression, and standardizing text formats, but also achieve rapid information aggregation and analysis through its powerful retrieval and integration capabilities. In course teaching, ChatGPT's application value further expands. For example, in STEM courses such as programming introduction, ChatGPT can assist students in code generation, error diagnosis, result feedback, and debugging optimization, thereby improving learning efficiency and experience [58], [59]. In language education, ChatGPT can personalize curriculum customization according to student needs, interests, and communication preferences, significantly promoting students' language learning [60]. Empirical research in biomedical education further validates ChatGPT's effectiveness in academic support and competency training. For example, ChatGPT can not only help medical students improve medical interview skills, clinical judgment, and comprehensive clinical abilities, but its rapid information acquisition capabilities can also support students in instant information retrieval and content summarization, thereby enhancing learning efficiency and professional competence [61], [62], [63]. Additionally, ChatGPT can support students in personalized learning and assist teachers in lesson preparation, content generation, and classroom teaching design, providing multi-dimensional intelligent support for educational scenarios [64].

Large language models such as Gemini and DeepSeek have also demonstrated high application potential and academic performance in multiple educational scenarios. In medical education, research comparing various models on anatomy education knowledge Q&A tasks showed that Google Gemini 2.5 Flash performed best, followed by Google Gemini 2.0, with both outperforming GPT-4 overall [65]. Another study systematically evaluated GPT-4 Turbo, Gemini Advanced, and LLaMA 3.1 on the Indian Foreign Medical Graduate Examination (FMGE) using 472 test questions. Results indicated that large language models can serve as effective supplementary tools for FMGE preparation, but perform relatively poorly in subjects requiring localized knowledge and complex clinical reasoning, such as public health, necessitating further expansion of question type coverage and strengthening of clinical application capabilities [66].

In programming education, research comparing Python code generation capabilities of ChatGPT, DeepSeek, and Gemini showed that DeepSeek had the highest code correctness and could generate passing solutions with fewer attempts, but had longer reasoning times when handling complex problems; Gemini had the fastest reasoning speed but only 40% code correctness, showing weaker performance in complex tasks; ChatGPT demonstrated balanced performance with moderate code maintainability but also had some resource usage efficiency issues. These comparative results provide important references for learners when choosing AI programming assistance tools [67].

In language learning, research has focused on IELTS writing score prediction tasks, comparing mainstream models including ChatGPT, Claude 3.5 Sonnet, Microsoft Copilot, and Google Gemini Flash. Results showed that ChatGPT-4 and ChatGPT-4o had the best prediction performance, providing IELTS candidates with a low-cost, efficient writing self-assessment tool with high practical application value [68].

5. Challenges in AGI-Enabled Education

The effective application of educational technology cannot be separated from deep integration with educational philosophy and practice, while also requiring comprehensive consideration of multiple factors including ethics, privacy, and fairness [69], [70], [71], [72]. Only on the basis of fully considering these factors can AI truly realize its transformative potential in education, creating better educational experiences and growth environments for every learner. This study selects several representative risks and challenges for focused analysis, with main content shown in Figure 3 [Figure 3: see original paper].

Figure 3 Potential Risks of AI in Education

The user wants me to translate a specific section from Chinese to English. The section is “### 5.1 Digital Divide” from an academic paper.

Let me analyze the content:

1. It starts with “### 5.1 Digital Divide” - this is the section heading
2. First paragraph discusses the digital divide as a bottleneck for educational digitalization, mentions the U.S. National Educational Technology Plan 2024, three aspects (digital access divide, digital design divide, digital use divide), references Figure 4, and mentions constraints on high-quality education development. Then it cites Wang et al. studying Chinese higher education institutions and AI capability dimensions.
3. Then there's “**Figure 4 Digital Divide**” - this is the figure caption
4. Next paragraph discusses what governments, institutions, and enterprises should do - collaborative policy formulation, infrastructure improvement, teacher digital capabilities, student digital literacy, etc. Mentions Table 4.

5. Then “**Table 4 Core Manifestations and Response Measures of the Digital Divide**” - table caption
6. Then the actual table with three dimensions: Digital Access Divide, Digital Design Divide, Digital Use Divide, each with core manifestations and response measures.

Key requirements: - Preserve ALL MATH - but I don’ t see any math in this section - Preserve ALL CITATIONS - keep [?], ??, (??) unchanged. I see [73] and [74] which should be kept as [?] and [?] or just [73] and [74] depending on the original format. Looking at the text, it uses [73] and [74] style, so I should preserve that. - Preserve ALL FIGURE/TABLE MARKERS - keep [FIGURE:N] and [TABLE:N] unchanged. I see [Figure 4: see original paper] and . - Maintain academic tone - Romanize author names using pinyin - I see “Wang et al.” which is already in English/pinyin - No Chinese characters left - I need to translate “普惠” which appears twice. “普惠” means “inclusive” or “benefiting all” or “universal access” . In the context of policies, it’ s often translated as “inclusive” or “universal” . Let me see the context: “设备普惠政策” and “普惠 accessibility design” . This should be “inclusive device policies” and “inclusive accessibility design” or “universal access policies” . “普惠” is a Chinese term meaning “benefiting all people” or “inclusive” . In policy contexts, it’ s often “inclusive” or “universal” . Let me think about the best translation. “普惠政策” could be “inclusive policies” or “universal access policies” . Given the context of digital divide, “inclusive” seems appropriate. “普惠 accessibility design” - maybe “universal design for accessibility” or “inclusive accessibility design” . I’ ll use “inclusive” for consistency. - Technical terms: Use standard English equivalents - DO NOT leave any Chinese characters

Let me go through the text carefully:

“The digital divide has always been a key bottleneck for countries promoting educational digitalization and intelligent transformation.” - Good start.

“With the rapid development of AI, the traditional digital divide is gradually evolving into a more complex, multi-dimensional divide.” - Good.

“The U.S. National Educational Technology Plan released in 2024 issued initiatives from three aspects: digital access divide, digital design divide, and digital use divide, as shown in Figure 4 [Figure 4: see original paper].”- Need to preserve [Figure 4: see original paper].

“Factors including infrastructure and device accessibility, education systems’ and teachers’ ability to integrate digital technology into teaching, and the depth and quality of different individuals and groups using digital technology to promote learning and teaching are all constraining high-quality education development [73].” - Preserve [73].

“In higher education contexts, Wang et al. studied four Chinese higher education institutions applying AI technology, verifying through modeling analysis that higher education institutions’ AI capability consists of three dimensions—

resources, skills, and awareness—and found that AI capability can significantly enhance students’ creativity and self-efficacy [74].” - Preserve [74]. “Wang et al.” is already romanized.

“**Figure 4 Digital Divide**” - Keep as is.

“Governments, educational institutions, and technology enterprises should collaboratively promote the formulation of policy systems that are both environmentally sensitive and equity-oriented, improving infrastructure construction and teaching condition gaps, and enhancing accessibility to the Internet and digital devices.” - Good.

“Simultaneously, improving teachers’ digital capabilities is crucial, necessitating systematic training to help teachers effectively integrate AI tools into teaching practice.” - Good.

“Additionally, teachers need to focus on cultivating students’ digital literacy and critical thinking, enabling students to deeply understand the potential uses and ethical implications of generative AI and other emerging technologies and to use AI tools effectively and purposefully.” - Good.

“Table 4 not only clearly presents the multi-dimensional structure of the digital divide but also reveals the causal mechanisms and governance priorities of each dimension, providing decision-making references for education managers, schools, and policymakers.” - Preserve .

“**Table 4 Core Manifestations and Response Measures of the Digital Divide**” - Keep as is.

Now the table:

Dimension	Core Manifestation	Response Measures
Digital Access Divide	Uneven network infrastructure, smart devices, and Internet access capabilities; widening gaps in access to large models and intelligent applications	Strengthen infrastructure construction; launch device 普惠 policies; promote 普惠 accessibility design for educational platforms and large models, making AI tools low-threshold and widely accessible

Dimension	Core Manifestation	Response Measures
Digital Design Divide	Huge differences in schools' and teachers' ability to integrate digital technology and AI tools into teaching; uneven design quality of teaching platforms, course resources, and learning systems; uneven digital governance capabilities of education systems, leading to "technologically available but educationally unavailable" situations in digital environment design, platform deployment, and technical support	Systematically improve teachers' digital capabilities, AI literacy, and technology integration skills; strengthen schools' digital governance capabilities; promote "educational adaptability design" of courses, teaching platforms, and learning resources; formulate norms and design standards for education systems using AI, ensuring platforms and courses follow usability, fairness, and learning science principles
Digital Use Divide	Different students use digital resources and AI tools for learning with varying depth and quality; obvious gaps in students' digital literacy, AI literacy, and critical thinking; teachers and parents have different levels of understanding and guidance ability regarding digital technology	Strengthen cultivation of students' digital literacy, AI literacy, and critical thinking; establish school-level digital support systems to provide usage guidance, learning tutoring, and technical help for students; guide parents and teachers to understand the value and boundaries of AI tools, improving guidance ability for technology use

I need to translate the Chinese parts in the table: - “设备普惠政策” -> “inclusive device policies” or “universal device access policies” . I ll use “inclusive device policies” . - “普惠 accessibility design” -> “inclusive accessibility design” (keeping “accessibility” as it’s already English) - “低门槛” -> “low-threshold” (this is already in the text as “low-threshold”) - “教育适应性设计” -> “educational adaptability design” (this seems to be a direct translation, but let me think if there’s a better term. In educational technology, “adaptive design” or “adaptive learning design” is common. But “educational adaptability design” might be a specific term. I ll keep it as is since it’s in quotes in the original.)

Wait, looking at the table again, I see “教育适应性设计” is in quotes as “educational adaptability design” . So I should keep that translation.

Let me double-check the table content for any other Chinese characters. The

table seems to have English terms already mixed in, but the core content is Chinese. I need to make sure I translate everything properly.

Actually, looking more carefully at the table in the original text, it appears to be a mix. Let me re-read:

“| **Digital Access Divide** | Uneven network infrastructure, smart devices, and Internet access capabilities; widening gaps in access to large models and intelligent applications | Strengthen infrastructure construction; launch device 普惠 policies; promote 普惠 accessibility design for educational platforms and large models, making AI tools low-threshold and widely accessible |”

The terms “device 普惠 policies” and “普惠 accessibility design” contain Chinese characters “普惠”. I need to translate these to English.

“普惠” means “inclusive” or “universal” or “benefiting all”. In the context of policies, “inclusive policies” is a standard term. For “accessibility design”, “inclusive design” is also a standard term. So: - “device 普惠 policies” -> “inclusive device policies” - “普惠 accessibility design” -> “inclusive accessibility design”

But wait, “accessibility design” is already English. So maybe it’s “普惠性无障碍设计” or something similar. Let me think about the original Chinese. “普惠” is an adjective meaning “inclusive” or “universal”. So “普惠 accessibility design” would be “inclusive accessibility design”. That makes sense.

Actually, I think the original might have been “普惠性设计” or similar. But given what’s written, I’ll translate “普惠” as “inclusive”.

So the translation would be: - “launch inclusive device policies” - “promote inclusive accessibility design”

But “inclusive accessibility design” is a bit redundant. “Accessibility design” already implies inclusivity. Maybe it’s “universal design for accessibility”? Or just “inclusive design”? Let me think about the context. The phrase is “promote 普惠 accessibility design for educational platforms and large models”. This could mean “promote universal accessibility design” or “promote inclusive design for accessibility”. I think “inclusive accessibility design” is fine, or maybe “universal accessibility design”. Given that “普惠” is often translated as “inclusive” in policy contexts, I’ll stick with “inclusive”.

Actually, looking at the broader context of digital divide, “普惠” often refers to making things accessible to everyone, especially disadvantaged groups. So “inclusive” is appropriate.

Let me finalize the translation:

For the table row “Digital Access Divide”: - Response Measures: “Strengthen infrastructure construction; launch inclusive device policies; promote inclusive accessibility design for educational platforms and large models, making AI tools low-threshold and widely accessible”

Wait, I should also check if there are any other Chinese characters. The table seems to be the main place. Let me scan the entire text again:

“The digital divide has always been a key bottleneck for countries promoting educational digitalization and intelligent transformation.” - OK “With the rapid development of AI, the traditional digital divide is gradually evolving into a more complex, multi-dimensional divide.” - OK “The U.S. National Educational Technology Plan released in 2024 issued initiatives from three aspects: digital access divide, digital design divide, and digital use divide, as shown in Figure 4 [Figure 4: see original paper].” - OK “Factors including infrastructure and device accessibility, education systems’ and teachers’ ability to integrate digital technology into teaching, and the depth and quality of different individuals and groups using digital technology to promote learning and teaching are all constraining high-quality education development [73].” - OK “In higher education contexts, Wang et al. studied four Chinese higher education institutions applying AI technology, verifying through modeling analysis that higher education institutions’ AI capability consists of three dimensions—resources, skills, and awareness—and found that AI capability can significantly enhance students’ creativity and self-efficacy [74].” - OK

“Figure 4 Digital Divide” - OK

“Governments, educational institutions, and technology enterprises should collaboratively promote the formulation of policy systems that are both environmentally sensitive and equity-oriented, improving infrastructure construction and teaching condition gaps, and enhancing accessibility to the Internet and digital devices.” - OK “Simultaneously, improving teachers’ digital capabilities is crucial, necessitating systematic training to help teachers effectively integrate AI tools into teaching practice.” - OK “Additionally, teachers need to focus on cultivating students’ digital literacy and critical thinking, enabling students to deeply understand the### 5.2 Teacher Role Transformation

As AI gradually penetrates core teaching links including knowledge transmission, skill demonstration, and learning diagnosis, teacher groups are facing unprecedented pressure for role transformation and capability reconstruction. Although AI can effectively assist teaching in curriculum planning, writing guidance, content production, and personalized feedback, its widespread application may also trigger academic misconduct, student over-dependence on technology, and hindered development of students’ critical thinking and comprehensive abilities. Therefore, teachers need not only to master and appropriately use AI tools but also to adhere to education’s essential goals, cultivating students’ correct values, critical thinking, and autonomous decision-making abilities [75], [76], [77], [78]. Teachers’ unique qualities including emotional and interpersonal skills, teaching abilities, and ethical considerations make AI unable to truly replace teachers [15]. In this complex and continuously evolving educational ecosystem, teachers’ importance in shaping student values, providing emotional support, and delivering humanistic care has not weakened but rather become more prominent.

Jinhee Kim conducted in-depth interviews with 20 leading Chinese AI education teachers, researching “Teacher-AI Collaboration” (TAC) and for the first time systematically defining the core dimensions and relational logic for effective TAC implementation, providing important references for educational design and teacher professional development [79]. In response to the demand for teacher capability structure transformation driven by rapid technological evolution, relevant scholars have constructed various teacher competency frameworks. For example, Hu et al. systematically reviewed and analyzed existing different types of frameworks, proposing a teacher competency framework comprising three dimensions—teacher cognition and emotion, teacher knowledge and skills, and interaction between teacher cognition and capabilities—and eight sub-dimensions, pointing out potential challenges for teachers in the AGI era and providing important references for future teacher professional capability development and transformation [80].

5.3 Data Privacy and Algorithmic Fairness

In the context of AI’s deep integration into the education system, data privacy and security, algorithmic transparency, and algorithmic bias have become key issues affecting AI application and educational equity realization, as shown in Figure 5 [Figure 5: see original paper].

Figure 5 Core Elements of AI Education Governance

In AI-enabled educational applications, data privacy and security are the prerequisite conditions and fundamental guarantees for technology implementation, with the core being protection of sensitive data throughout the entire educational process. Applications such as intelligent teaching assistance, learning situation analysis, and personalized learning require deep processing and analysis of massive, multi-dimensional educational data. Therefore, during data collection, transmission, and use, it is necessary to prevent illegal acquisition, abuse, leakage, or tampering of data to effectively safeguard student privacy and data security [81], [82].

Algorithmic transparency is a key prerequisite for avoiding implicit bias and enhancing trust in AI among academia and educational practitioners [83]. In AGI-enabled educational application scenarios, algorithmic transparency enables teachers to more clearly understand intelligent systems’ decision-making processes, thereby enhancing the perceptibility and controllability of teaching processes. However, transparency practice faces dual tensions: on one hand, excessive emphasis on transparency may lead to leakage of enterprises’ core technologies; on the other hand, overprotecting technical secrets may plunge algorithms into a “black box” state, weakening educational subjects’ right to know and supervise. Therefore, it is necessary to explore reasonable algorithmic transparency implementation paths that balance commercial secret protection with educational responsibility.

Algorithmic bias continues to affect educational fairness, becoming a key obsta-

cle to high-quality development of AI-enabled education [84], [85]. If training data is biased in terms of populations or cultures, model outputs may present unfair or even discriminatory results, which not only directly affects students' learning experiences and academic performance but may also further solidify educational gaps, violating the fundamental concept of educational equity [76]. Existing research has conducted comparative evaluations of social and gender bias in three mainstream large language models: ChatGPT, Gemini, and Claude. Results show that ChatGPT consistently exhibits bias, Gemini occasionally shows bias, while Claude has relatively low bias levels [86]. This research reveals significant differences in bias levels among large language models and further calls for strengthened AI bias governance strategies to ensure fairness in AI applications in education.

6. Conclusion and Outlook

This study systematically reviews the evolutionary trajectory of educational models from traditional education through digital and online education and intelligent education to AGI-driven education, revealing the profound impact of technological iteration on educational paradigm transformation. The research shows that core technologies such as intelligent teaching assistants, XR technology, and large language models are comprehensively penetrating key links including knowledge presentation, learning support, learning diagnosis, and teaching management, driving education from a "technology-assisted" stage to a new stage of "intelligent symbiosis."

However, the process of AGI enabling education is also accompanied by a series of challenges that directly relate to core demands of educational equity, quality, and ethics. Therefore, while promoting technological development and application deepening, it is also necessary to construct a comprehensive governance system to ensure standardized and rational application of AGI in the education field. AGI is leading education into a new paradigm transformation period. Future education development should, under the synergistic effect of technology, concepts, and institutions, construct a more inclusive, efficient, and flexible new educational ecosystem.

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Note: Figure translations are in progress. See original paper for figures.

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