Educational Paradigm Transformation Driven by Artificial General Intelligence: From Early Childhood Enlightenment to Lifelong Learning

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Date: 2026-01-08T17:37:06+00:00

Abstract

With the breakthrough emergence of large language models such as ChatGPT and Gemini, artificial general intelligence (AGI) is rapidly progressing from a technological vision toward real-world applications. AGI is gradually reshaping the foundational logic of the educational ecosystem, driving a transformation of education from being "staged and standardized" toward becoming "lifelong, personalized, and human–machine symbiotic." Existing reviews are mostly confined to a single educational stage or specific disciplinary context, and few studies have systematically examined the applications and impacts of AGI across the entire education system from a full life-cycle perspective. Drawing on representative literature from China and abroad, this paper systematically reviews, from the perspective of whole-of-life education, the application scenarios, shifts in educational philosophy, and practical cases of AGI in early childhood education, primary and secondary education, higher education, and lifelong learning, with the aim of providing references for constructing a fair and sustainable AGI-enabled educational ecosystem.

Full Text

Educational Paradigm Shift Driven by Artificial General Intelligence: From Early Childhood to Lifelong Learning

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Abstract

The emergence of Large Language Models such as ChatGPT and Gemini signals that Artificial General Intelligence (AGI) is accelerating from a technical vision to practical application. AGI is progressively reshaping the foundational paradigms of the educational ecosystem, driving a transition from "stage-based and standardized" models to "lifelong, personalized, and human-AI symbiotic" learning. Most existing reviews are limited to specific educational stages or particular disciplinary contexts; few studies have systematically examined the applications and impacts of AGI across the entire educational system from a lifelong learning perspective. Synthesizing representative literature, this paper systematically reviews the application scenarios, pedagogical shifts, and practical cases of AGI from a holistic perspective spanning early childhood, K-12, higher education, and lifelong learning. The findings aim to provide insights for building an equitable and sustainable AGI educational ecosystem.

Keywords: Artificial General Intelligence; Lifelong Learning; Large Language Models; ChatGPT; Personalized Learning

1. Introduction

In contemporary society, Artificial General Intelligence (AGI) is gradually transitioning from theoretical concept to verifiable technical prototype, becoming a new focal point in artificial intelligence research. Unlike Artificial Narrow Intelligence (ANI), which is confined to specific rules or single tasks, AGI is defined as an intelligent system possessing human-like cognitive flexibility capable of performing any human intellectual task. [Figure 1: see original paper] illustrates the characteristics and involved disciplines of AGI. Thanks to breakthroughs in large model architectures, rapid improvements in computing power, and the maturation of multimodal learning mechanisms, large language models such as ChatGPT[?, ?, ?] and Gemini[?, ?] have demonstrated human-like general intelligence in reasoning, planning, and language understanding, and are regarded by academia as early prototypes and practical carriers of AGI systems[?]. This technological leap not only promotes the widespread application of AGI in science, healthcare, economics, and other fields, but also, by reshaping society' s definition of core human competencies, prompts academic and policy circles to reflect on the reconstruction of the educational system in the "post-AI era." On one hand, AGI brings enormous possibilities for the future development of education, enabling rapid changes in educational practice patterns[?, ?]; on the other hand, it has triggered intense debates about the future of education and the role of human educators[?, ?].

Building upon this foundation, this paper uses large language models as a starting point to deeply explore the educational paradigm reconstruction driven by this technological leap. In the educational domain, the deep integration of AGI is reshaping the entire educational ecosystem from early childhood enlightenment to lifelong learning, and redefining teaching paradigms[?, ?, ?]. With its inherent broad cognitive capabilities and adaptability, AGI can precisely respond to students' individual needs, dynamically adjust teaching strategies through comprehensive performance feedback, and provide exclusive learning experiences for every learner[?]. While AGI accelerates the processes of teaching personalization, evaluation intelligence, and resource democratization, it also brings profound structural challenges. As Kasneci et al.[?] point out in their empirical analysis of large language models' impact on education, this disruptive technology has profoundly impacted the existing education system, not only breaking the stage-divided and standardized evaluation-centered structure of traditional education, but also exposing the lag in existing educational governance systems, ethical norms, and equity assurance mechanisms when facing technological upheavals.

[Figure 1: see original paper] illustrates the characteristics and disciplines of AGI. However, existing reviews are mostly limited to single educational stages or specific disciplinary contexts, such as higher education[?, ?, ?], K-12 education[?, ?], or early childhood education[?]; or they focus only on specific disciplinary scenarios such as medicine[?], chemistry[?], STEM education[?], physics[?], art and design[?], and mathematics[?]. Few studies have systematically reviewed the applications and impacts of AGI across the entire education system from a whole-lifecycle perspective. This paper adopts a "whole-cycle education" analytical perspective to systematically explore the overall transformation path of the education system empowered by AGI, as shown in [Figure 2: see original paper]. Whole-cycle education refers to a continuous cultivation process from early childhood enlightenment to lifelong learning, emphasizing the continuous integration of ability development, learning habits, and social adaptation mechanisms throughout the entire journey. This perspective breaks through traditional educational stage thinking, aiming to construct an open learning ecosystem that connects different age groups and learning scenarios. Based on this foundation, this paper analyzes various aspects including application scenarios, educational concept changes, and practical cases across different educational stages, providing a systematic theoretical framework and practical reference for AGI-driven educational transformation. The contributions of this paper are as follows:

1. We propose a whole-cycle framework from early childhood enlightenment to lifelong learning in the AGI era, systematically clarifying the differentiated functions of AGI-empowered education at various stages, providing a reference basis for holistic educational practice transformation.
2. We summarize the educational model innovations driven by AGI, and through systematic review of the practical paths and empowerment mechanisms of AGI in four distinct stages—early childhood enlightenment, K-12 education, higher education, and lifelong learning—reveal the core positioning of AGI as a deeply involved human-AI symbiotic intelligent system in teaching decision-making and learning processes.

The remaining sections are organized as follows: Section 2 provides an overview of educational transformation in the AGI era; Sections 3 through 6 respectively discuss the key transformation points and application cases in early childhood, K-12, higher education, and lifelong learning stages; Section 7 presents conclusions and future outlooks.

[Figure 2: see original paper] illustrates the framework of AGI-empowered whole-cycle education system.

2. Educational Transformation in the AGI Era

2.1 Shift in Educational Philosophy

In the AGI era, educational philosophy faces systematic reconstruction. Learning is no longer merely a process of acquiring knowledge and skills, but a pathway to cultivating critical thinking, creativity, and collaboration abilities, thereby empowering individuals to address complex challenges and drive social progress. Specifically, this section elaborates on the transformation of educational philosophy from five key dimensions: educational objectives, educational models, learning spatiotemporal dimensions, evaluation systems, and educational resources, as shown in .

illustrates the transformation of educational philosophy in the AGI era.

From the perspective of educational objectives, the focus of talent cultivation is gradually moving beyond the traditional scope of pure knowledge transmission toward comprehensive cultivation of higher-order abilities. In traditional education, students primarily master knowledge through memorization and repetitive practice. However, as artificial intelligence evolves toward AGI, education increasingly emphasizes critical thinking, metacognitive abilities, humanistic and social skills, and interdisciplinary knowledge transfer capabilities[**?**]. This evolutionary trend enables intelligent systems to leverage AGI' s generative and reasoning capabilities, guiding students to apply knowledge and enhance comprehensive abilities through task generation, case analysis, and virtual experiments, thereby meeting future societal demands for innovative talents.

From the perspective of educational models, teaching forms are undergoing a transformation from traditional teacher-centered instruction to human-AI collaboration and learning communities. Research surveys[**?**] have found that students are more willing to integrate generative AI technology into their learning practices, as it can provide instant feedback, answers, or guidance without requiring them to wait for teacher responses. In this new paradigm, teachers are no longer the sole source of knowledge but collaborate with AGI to construct learning environments. Students actively participate in knowledge construction through collaboration, autonomous exploration, and personalized training, while teachers transform into learning designers and facilitators, forming a student-centered intelligent learning ecosystem.

From the perspective of learning spatiotemporal characteristics, the boundaries of space and time are being reconstructed, with education continuously evolving from stage-based to lifelong learning paradigms. Generative AI has triggered epistemological-level transformations, no longer limited to providing fixed knowledge points but supporting learners in constructing personalized lifelong learning paths anytime and anywhere[?]. AGI breaks down barriers between formal and informal learning by integrating cross-scenario and cross-disciplinary resource ecosystems. Early research has confirmed that AGI-like intelligent tutoring robots already possess the ability to recommend adaptive content based on learning styles[?]. Under the AGI vision, this adaptability is further upgraded to deep understanding and instant response to individual whole-lifecycle data, truly integrating learning seamlessly into individuals' daily lives and work.

Regarding learning evaluation and educational resources, both are undergoing structural reshaping from static singularity to dynamic diversity. In evaluation systems, the educational paradigm shifts from single knowledge tests focusing on results to comprehensive competency evaluation focusing on processes. For example, AGI can generate adaptive learning materials based on student abilities and assist in implementing high-frequency formative evaluations[?]. Additionally, AGI constructs a multi-dimensional evaluation system centered on learners' holistic growth by deeply understanding their psychological motivations, cognitive load, and ability development trajectories. In educational resources, AGI breaks the physical boundaries of traditional textbooks and closed classrooms, utilizing its powerful multimodal generation and heterogeneous data processing capabilities to achieve deep integration and real-time updates of cross-platform and cross-domain resources, ensuring learning content can dynamically adapt to students' personalized needs.

2.2 Teacher Role Transformation

Due to the reconstruction of educational paradigms, the human-AI symbiotic environment forces teachers to transform from single knowledge transmitters to learning designers, facilitators, and emotional supporters[?]. Therefore, AGI technology should be regarded as a tool to enhance teachers' instructional capabilities rather than a threat that marginalizes teacher functions. As shown in , the intervention of AGI technology promotes the evolution of teacher functions in four aspects: instructional design, interaction methods, learning evaluation, and value guidance.

illustrates the evolution of teacher functions: from knowledge transmission to human-AI collaboration.

On one hand, in instructional design and interaction, teachers need to shift from transmitting established knowledge to constructing complex cross-disciplinary contexts and inquiry tasks. Leveraging AGI' s generative and reasoning capabilities, teachers guide students to apply knowledge and enhance comprehensive abilities in practice. However, to achieve this transformation, the capability gap in technology integration must be bridged. Tan et al.[?] systematically review that urgent attention is needed on how teachers can master strategies for intelligent technology application in education from the perspective of promoting students' deep learning, and clarify its ethical boundaries. Meanwhile, in teaching interactions, teachers must play an irreplaceable emotional bond role, focusing on compensating for AGI' s deficiencies in deep emotional interaction and humanistic care.

On the other hand, in learning evaluation and value guidance, teachers' focus is shifting toward deep analysis of student growth trajectories while guiding students on proper AGI usage. The reconstructed evaluation system requires teachers to be liberated from tedious homework grading, using AGI to collect data on student interaction behaviors and problem-solving strategies to form dynamic comprehensive competency profiles. At this point, teachers' responsibility is to deeply interpret these multimodal data, focusing on students' critical thinking and innovative potential rather than simply counting scores. Simultaneously, as Tlili et al.[?] warn in their research on ChatGPT as a "double-edged sword," the inherent data biases and "hallucination" phenomena of intelligent models may subtly mislead learners' cognitive judgments. Therefore, in the increasingly tight human-AI collaboration context, teachers must 致力于 cultivating students' critical algorithmic literacy, guiding them to examine the authenticity and potential biases of generated content, thereby upholding educational ethical bottom lines and fairness principles while utilizing technology to enhance learning efficiency.

2.3 AGI-Empowered Educational Application Scenarios

Accompanying the functional reconstruction of teacher roles, the application scenarios of educational systems are also being reshaped by AGI. Unlike traditional AI that only focuses on automated assistance for single tasks, AGI constructs a comprehensive, intelligent educational application ecosystem through its core capabilities of cross-domain knowledge transfer, multimodal information processing, and autonomous task planning. This section introduces AGI' s roles and practical forms in different educational scenarios from three application contexts: cross-disciplinary navigation for knowledge construction, cognitive-emotional dual adaptation for individual development, and human-AI collaborative dual-teacher classrooms for teaching implementation.

Scenario 1: Generative Cross-Disciplinary Navigation for Knowledge Construction. AGI overcomes the limitations of traditional textbooks' linear structure and static presentation by building a cross-disciplinary learning navigation system centered on knowledge graphs through its cross-domain semantic understanding and knowledge recombination capabilities. Such systems not only possess powerful natural language understanding abilities but also serve as cognitive engines that automatically analyze massive academic resources, identify conceptual associations between different disciplines, and construct multi-dimensional cross-disciplinary knowledge networks. Pan et al.[?] point out in their roadmap for intelligent technology integration that unifying the general reasoning capabilities of large language models with the structured characteristics of knowledge graphs can automatically extract complex relationships from massive unstructured data, promoting educational knowledge management from static storage to generative recombination.

Scenario 2: Cognitive-Emotional Dual Adaptive Interaction for Individual Development. AGI achieves dual adaptation of cognition and emotion through deep data perception, driving education' s transformation from "standardized infusion" to "precision drip" personalization paradigms. In the cognitive dimension, AGI integrates and upgrades deep learning-based knowledge tracing algorithms, enabling real-time analysis of students' learning histories and knowledge mastery levels to generate tailored learning paths and dynamically adjust difficulty. For example, Piech et al.[**?**] introduced recurrent neural networks into student knowledge modeling, achieving high-precision learning state tracking without manual annotation; under the AGI vision, this mechanism is further optimized, with recent research confirming its significant potential for improving learning efficiency in higher education[**?**]. In the emotional dimension, affective computing becomes the key technology for achieving "warm education." AGI can monitor learners' attention states and emotional fluctuations in real-time by recognizing facial expressions, voice intonations, and interaction behaviors. D' Mello et al.[**?**] developed an intelligent tutoring system (Gaze Tutor) that detects "mind-wandering" states by tracking students' eye movement trajectories and automatically initiates dialogues for guidance when attention is detected as distracted. Building upon this, AGI further strengthens multimodal fusion capabilities, accurately predicting academic performance in online learning environments by integrating learners' facial expressions and voice intonation data, and generating differentiated emotional support strategies accordingly[**?**]. When negative emotions are detected, AGI can instantly provide personalized intervention suggestions or encouragement, significantly enhancing learning motivation and interaction quality while ensuring the educational process balances knowledge acquisition with psychological well-being.

Scenario 3: Human-AI Collaborative Dual-Teacher Classroom for Teaching Implementation. AGI is liberating teachers from mechanical labor and constructing efficient "dual-teacher collaborative" teaching scenarios. In this context, AGI evolves into an intelligent teaching assistant with high-level cognitive capabilities, deeply participating in instructional design optimization, automatic evaluation feedback, and multimodal resource recommendation, significantly enhancing the scientific nature of educational decision-making. The feasibility of this scenario has been validated in practices at top universities. Georgia Tech' s latest version of the virtual teaching assistant Jill Watson, powered by generative AI, has successfully achieved deep understanding of course content and high-frequency interaction with students, with performance significantly surpassing traditional assistant services[**?**]. This "teacher-AGI-student" ternary collaboration model not only allows teachers to return to their core roles of emotional guidance and nurturing but also drives the educational ecosystem toward greater efficiency, transparency, and fairness.

3. Early Childhood Education

3.1 Intelligent Teaching Content and Methods

In early childhood education, AGI applications have transcended traditional tool-level assistance, triggering systematic transformations in teaching content and methods. Unlike conventional technologies that serve merely as knowledge transmission carriers, AGI, with its powerful generative capabilities and multimodal interaction features, initiates early childhood education reforms and constructs a child-centered intelligent enlightenment ecosystem.

At the content level, AGI drives a paradigm shift from "static standardized resources" to "dynamically generated content." Traditional early childhood education relies on fixed materials such as picture books and nursery rhymes, making it difficult to precisely match each child' s interests and cognition. Thanks to generative AI breakthroughs, intelligent systems now possess real-time feedback capabilities, instantly constructing customized narratives and game tasks based on children' s preferred characters, scenarios, or current emotions. Su and Yang[?] emphasize in their theoretical framework that utilizing generative AI seamlessly embeds core parenting objectives such as language development and logical thinking into dynamically generated fairy tale narratives and role-playing. This mechanism transforms educational objectives from rigid infusion to natural realization through "learning by play," breaking traditional teaching' s rigid boundaries while meeting children' s individualization. This real-time calculation and adaptive adjustment mechanism based on data not only circumvents the "one-size-fits-all" limitation of traditional textbooks but also fundamentally ensures the continuous attractiveness and appropriateness of learning experiences.

At the methodological level, early childhood education is undergoing a transformation from single directive instruction to generative gamified inquiry. Traditional early childhood intelligent hardware is often limited by preset programs, providing only mechanical Q&A interactions that cannot adapt to children' s divergent thinking characteristics. Bertacchini et al.[?] introduced large language models into social robots, validating a novel adaptive dialogue teaching method where the system no longer relies on fixed scripts but possesses the ability to process unstructured interactions. It can follow children' s unrestrained imagination for instant story co-creation and logical guidance, thereby completing cognitive intervention within natural conversational flow. Moreover, AGI-era education is not only cognitive interaction but also emotional resonance. Given that generative AI already possesses high-level emotional awareness[?], a new generation of intelligent teaching assistants is evolving into empathetic growth partners capable of accurately capturing and responding to young children' s emotional changes. AGI-empowered teaching environments have been proven to significantly enhance learning agency[?], fostering psychological security that propels children from passive reception to autonomous exploration.

3.2 Personalized Early Learning

While teaching content and method reforms primarily affect external forms, AGI-empowered personalized early learning delves into children' s internal cognitive construction mechanisms. Personalized early learning is reflected not only in the adaptation of knowledge content but more importantly in cultivating children' s learning motivation, metacognitive abilities, and exploration habits. As shown in , compared with traditional models, AGI-assisted early childhood education achieves structural leaps in interaction logic, perception mechanisms, and guidance strategies. This section uses this framework to analyze how AGI provides comprehensive precision support for individual children.

illustrates AGI-driven personalized early learning: comparison between traditional and AGI-assisted models.

In terms of interaction logic, AGI algorithms create engaging interactive learning experiences for children by enhancing digital tool design and usability and improving learning resource accessibility[?]. For example, AGI-like intelligent robot toys can effectively stimulate young children' s personal interests, guiding them from passive observation to active questioning and exploration in interactions[?]. AGI constructs an adaptive interaction cycle driven by real-time individual behavior feedback, achieving deep personalization. Through progressive task design, instant feedback, and reward mechanisms, it enables children to form an individual-characteristic "trial-reflection-adjustment" learning cycle. This trend is already emerging in current research, with a typical case being MIT' s PopBots platform, which allows children to understand AI basic logic by training social robots[?]. In this process, children must continuously adjust their teaching strategies based on the robot' s real-time feedback, thereby strengthening logical reflection and metacognitive abilities through the iteration of "teaching" and "learning." This enlightenment model based on individual interaction trajectories lays important psychological and behavioral foundations for personalized learning in subsequent educational stages.

In terms of perception mechanisms, AGI-empowered personalized early learning manifests as a shift from responding to single learning performances to continuous modeling and dynamic understanding of individual children' s states. AGI possesses deeper perception capabilities, comprehensively recognizing children' s attention distribution, emotional fluctuations, and strategy choices across different tasks, and adjusting learning content and interaction methods in real-time based on this information. AI-based tutoring systems primarily focus on dynamically adjusting assistance intensity within single knowledge domains by analyzing children' s immediate operational feedback (such as task completion and reaction time)[?]. However, this mechanism remains at the "local response" level, making it difficult to achieve truly personalized early learning. To overcome this limitation, AGI introduces advanced cognitive architectures that integrate memory and reflection mechanisms. As Xi et al.[?] elaborate in their survey on the rise of large model agents, a new generation of intelligent agents can retrospectively identify emotional trigger points and causal relationships in individual interaction histories, thereby generating guidance strategies with temporal continuity. This perception mechanism based on children’ s long-term behavioral patterns enables the system to differentiate children’ s varied responses to similar tasks, achieving truly individual-oriented precision support and effectively ensuring their deep engagement in complex tasks.

In terms of guidance strategies, AGI-empowered personalized early learning is manifested as real-time precise regulation of individual children’s cognitive zones. Unlike traditional early learning models that primarily rely on age stratification, AGI systems act as intelligent learning companions, real-time perceiving children’ s cognitive load and dynamically adjusting task difficulty. Specifically, when monitoring that children can complete tasks independently, AGI automatically reduces assistance frequency to promote independent exploration; when detecting cognitive blocks or frustration emotions, it instantly breaks down objectives or provides hint-based clues. This high-frequency dynamic adjustment based on individual states rather than group averages enables each child to continuously learn within their own “zone of proximal development,” highlighting AGI’ s core value in achieving personalized support during early childhood enlightenment.

4. K-12 Education

4.1 Personalized Learning

The K-12 stage is a critical period for cognitive structure transition from concrete to abstract logical thinking. Faced with significant individual differences among students, traditional uniform classrooms struggle to break the boundary between “scale” and “personalization.” Leveraging its powerful semantic understanding and generative reasoning capabilities, AGI reshapes the underlying logic of personalized learning by constructing high-precision cognitive digital twins and generative learning fields.

Addressing the deep needs of K-12 personalized learning, AGI can dynamically adjust generative content and adaptive difficulty to achieve precise matching of teaching resources. Specifically, AGI systems can adapt to each student’ s learning pace, real-time judging their comprehension level by recognizing nonverbal cognitive cues (such as eye gaze and facial expressions), and providing remedial or advanced content accordingly[**?**, **?**]. Additionally, in K-12 education, AGI provides teachers with rich subject knowledge, personalized lesson plans, and teaching resource expansions, helping teachers break free from textbook limitations and create more personalized and engaging learning experiences for students.

Overall, AGI should be regarded as a supplementary tool to promote differentiated teaching and enhance teachers’ subject knowledge, not a replacement. Although it can provide adaptive feedback for students by recognizing cognitive cues and offer customized resources for classrooms, it still requires human teachers to perform necessary fine-tuning of generated content to ensure it truly aligns with students' psychological development levels, learning styles, and preferred information and activities.

4.2 From Multi-dimensional Diagnosis to Precision Intervention

In the K-12 education system, AGI can construct an intelligent closed loop of "real-time perception - deep diagnosis - precision intervention." Learning Analytics is an important support for intelligent K-12 education, and intervention measures based on learning analytics can greatly improve student learning outcomes[?]. Unlike traditional learning analytics that only remain at static statistics of historical performance, AGI transforms educational decision-making from experience-driven to data-driven by real-time monitoring of students' cognitive states and problem-solving processes. This section elaborates on how AGI reshapes K-12 students' learning error correction and feedback mechanisms from two aspects: multi-dimensional diagnosis and predictive precision intervention.

At the diagnosis and analysis level, AGI enables deep insights into the entire learning process. Specifically, it can comprehensively capture students' knowledge mastery, problem-solving strategy preferences, and classroom participation, focusing not only on "what was done wrong" but more importantly on analyzing "why it was wrong." This deep diagnostic capability is particularly prominent in complex interdisciplinary STEM project-based learning scenarios. Liao et al.[?] point out that new-generation intelligent teaching systems can not only real-time analyze Python code written by students through code evaluation modules but also precisely quantify students' cognitive load and strategy choices during debugging processes by combining interaction logs. This multi-dimensional diagnosis transcends single-outcome evaluation, accurately identifying whether students have logical fallacies, syntax errors, or metacognitive strategy deficiencies, providing high-precision diagnostic reports for subsequent interventions.

At the intervention and feedback level, AGI reshapes previous teaching support systems that relied on preset resources by continuously perceiving individual behaviors and cognitive states during learning processes, thereby achieving instant and precise adaptive interventions. AGI no longer waits until after exam failures to intervene but uses generative reasoning capabilities for predictive intervention at the early stages when students experience cognitive stagnation or emotional lows. For example, when monitoring continuous frustration in students during mathematical modeling tasks, the system automatically decomposes task difficulty, instantly generates targeted heuristic questions or step-by-step guidance prompts, and real-time adjusts support intensity during intervention. AGI-empowered adaptive interventions can significantly optimize learners' motivation and behavior patterns[?], achieving precision assistance through deep interaction and effectively breaking the vicious cycle of "falling behind - frustration - declining performance."

5. Higher Education

5.1 Research Capacity Cultivation

In the AGI era, talent cultivation objectives in higher education are facing reconstruction. The educational focus is gradually shifting from standardized knowledge infusion to comprehensive shaping of students' independent research capabilities and frontier problem-discovery abilities. This section elaborates on the transformation path of AGI-empowered research capacity cultivation from two aspects: knowledge acquisition and research training.

In the knowledge acquisition phase, AGI can real-time monitor research frontiers by automatically retrieving academic literature, integrating knowledge points, and generating summaries, helping students quickly understand core concepts and development trends in research fields. For example, Wu et al.[?] propose an automatic review generation method based on large language models, enhancing research productivity and literature recommendation efficiency. Additionally, research shows that large language models (GPT-4) can generate a complete original scientific research paper, including experimental hypotheses, data, and images, without human intervention[?].

During research training, AGI can serve as an intelligent assistant for experimental design and data analysis across various basic disciplines. Based on AI as a powerful paradigm for scientific research[?], AGI achieves further upgrades, capable of proposing experimental scheme suggestions, simulating experimental results, generating data visualization charts, and providing analysis and improvement suggestions according to research objectives and experimental conditions. For example, generative AI represented by ChatGPT is significantly improving work efficiency, especially in statistics and data science, where they can assist in generating code, analyzing data, and fitting models[?]. This assistance not only improves experimental efficiency but also enhances students' data processing capabilities and scientific thinking, enabling them to conduct independent judgment and innovative practice in complex research contexts.

5.2 Interdisciplinary Learning

Facing increasingly complex scientific problems and social challenges, interdisciplinary learning has become a core pathway for higher education to cultivate compound innovative talents. However, in traditional learning models, knowledge transfer is often constrained by disciplinary barriers and experiential limitations, making it difficult for learners to efficiently apply existing knowledge structures to new fields. The emergence of AGI provides new possibilities for cross-domain knowledge transfer. With its powerful semantic understanding, reasoning, and pattern recognition capabilities, AGI can perform deep modeling and semantic alignment of knowledge across different disciplines, thereby achieving interdisciplinary transfer and recombination of concepts, methods, and skills. For example, Moor et al.[?] reveal in their research on generalist medical artificial intelligence that foundation model-based intelligent systems already possess cross-modal semantic parsing capabilities, enabling AGI to help engineering learners quickly understand the core algorithms and clinical logic behind medical image analysis, breaking cognitive barriers between engineering and medicine.

Moreover, AGI is not limited to "knowledge transfer" but can also promote innovation in cross-domain knowledge fusion. Through multimodal learning and analogical reasoning, AGI can cross-integrate knowledge from different fields. Large language models have demonstrated emergent zero-shot analogical reasoning capabilities, capable of identifying deep structural similarities across different knowledge domains beyond the boundaries between abstract symbols and concrete situations[?]. Relying on deep logical mapping capabilities, AGI breaks through traditional single-disciplinary boundaries and is widely applied to generate creative new ideas and methods. For example, Boiko et al.[?] developed an intelligent agent system that successfully integrated massive chemical literature from the internet, Python code writing, and laboratory hardware control knowledge to autonomously design and execute complex chemical reactions, demonstrating AGI' s enormous potential in interdisciplinary innovative practice.

5.3 Diversified Evaluation System

Although diversified evaluation is also valued in basic education, its urgency and implementation difficulty present fundamentally different characteristics in higher education. While basic education focuses primarily on benchmark knowledge learning and core competency germination, higher education requires students to possess the ability to solve complex open-ended problems, interdisciplinary innovative thinking, and professional skills directly aligned with job positions. Traditional standardized examinations and GPA systems struggle to quantify these higher-order cognitive abilities and implicit competencies, resulting in a long-standing disconnect between evaluation results and talent cultivation objectives. AGI intervention alleviates this challenge to some extent by processing high-dimensional, multimodal data and driving the evaluation system to shift from traditional summative examinations to whole-process, multi-dimensional approaches.

In specific evaluation dimensions, AGI-empowered evaluation systems establish comprehensive competency-centered assessment. Agent technology is driving the evaluation paradigm transformation from summative to formative evaluation[?]. AGI can deeply penetrate the entire process of course learning, research training, and social practice, real-time capturing micro-data on students' interaction behaviors, problem-solving strategies, and collaborative communication. Simultaneously, AGI can overcome challenges in evaluating critical thinking and leadership through deep semantic reasoning technology, transforming unstructured data into dynamic comprehensive competency profiles, providing core support for panoramic evaluation beyond traditional GPA.

Furthermore, regarding evaluation of project outcomes and practical abilities, AGI demonstrates powerful intelligent analysis potential. In scientific research projects, innovative experiments, and internships, students often produce non-standard answers such as code, design drawings, and experimental reports. AGI can not only score the accuracy of experimental results but also automatically analyze the logical rigor of experimental reports, code operational efficiency, and innovation degree of design schemes. For example, when generative AI evaluates complex scientific tasks, it can already achieve scoring reliability highly consistent with human experts[**?**], and can provide generative diagnostic feedback beyond mere scores, thereby achieving deep integration of evaluation and learning. This capability enables higher education to break through the dual limitations of single-result orientation and manual grading, achieving comprehensive evaluation of multi-dimensional evidence including students' research processes, practical performance, and innovative contributions while implementing at scale, thus constructing an evaluation system that truly reflects diverse competency structures.

6. Lifelong Learning

Against the backdrop of rapid labor market iteration, lifelong learning has transformed from a conceptual advocacy to a survival necessity for individuals to cope with uncertainty. However, traditional education models struggle to solve the pain point of misalignment between learning resources and career needs. AGI can transform lifelong learning paradigms, driving the learning system to evolve into an adaptive ecosystem capable of real-time responding to individual development needs and external career environment changes. As Duan and Wu[**?**] point out in their research on generative AI for career planning, intelligent systems already possess the ability to integrate labor market insights and individual development data. Using this multi-dimensional data insight as a decision-making engine, AGI dynamically generates personalized learning paths by integrating personal learning profiles, career portraits, skill development status, and social job demands, providing targeted learning support at different life stages. This lifelong learning mechanism emphasizes not only knowledge acquisition but also competency cultivation and career adaptation.

AGI reshapes the technical foundation of lifelong learning by leveraging large language models' strong semantic understanding capabilities and intelligent agents' autonomous planning abilities. Large language models can understand complex professional skill descriptions and unstructured personal experiences, real-time generating personalized learning content and transfer paths; while multi-agent systems play the role of real-time accompanying intelligent learning guides. For example, Wang et al.[**?**] propose a large model-based multi-agent collaborative framework where the system can autonomously plan optimal learning strategies according to career goals through division of labor and collaboration among agents for skill identification, learner profiling, and path scheduling, thereby compensating for the shortcomings of single knowledge graphs in dynamic reasoning and personalized generation. On this foundation, the combination of micro-credentials, digital badges, and AGI-generated competency evidence chains not only provides credible certification mechanisms for informal learning but also offers employers high-granularity talent assessment basis, effectively reducing friction costs of career transitions.

In summary, AGI-driven lifelong learning transformation has surpassed single knowledge acquisition tools, constructing an intelligent ecological closed loop integrating "skill cultivation, competency certification, and career matching." By bridging the value gap between learning outcomes and the labor market, it lays an institutional foundation for society to cultivate compound talents with lifelong growth awareness and professional anti-fragility.

7. Conclusion and Outlook

Based on the background of AGI technology' s breakthrough evolution, this paper constructs a "whole-cycle education" analytical framework spanning early childhood enlightenment to lifelong learning, systematically demonstrating the fundamental transformation of educational paradigms from singular "knowledge transmission"to bidirectional interactive "human-AI symbiotic intelligence." Leveraging the generative capabilities of large language models and planning capabilities of multi-agents, AGI achieves differentiated deep empowerment across educational stages: reshaping contextualized experiences in early childhood education through multimodal emotional interaction; implementing scaled personalized teaching in K-12 through cognitive digital twins and predictive interventions; reconstructing innovative talent cultivation models in higher education through generative research assistance, interdisciplinary learning, and competency-oriented diversified evaluation; and breaking traditional education' s spatiotemporal barriers in lifelong learning through cross-domain knowledge transfer and dynamic job adaptation mechanisms. This whole-cycle perspective not only reveals the continuous logic of competency generation across educational stages but also proves that AGI is a key driver for education' s evolution from "stage-based reserve" to "lifelong, personalized learning" ecosystems.

Facing opportunities and challenges brought by AGI' s deep integration, future educational transformations need to seek collaborative breakthroughs at technical, pedagogical, and policy levels to build a fair and trustworthy intelligent education ecosystem. At the technical level, focus should be on developing education-specific large models with high interpretability and privacy protection capabilities, eliminating "algorithmic black boxes" and bias risks through causal reasoning and alignment technologies. At the pedagogical level, the cognitive boundaries of human-AI collaboration need to be further clarified, establishing new subject relationships under the "teacher-AGI-student" ternary structure. At the policy level, countries should formulate and continue developing general AI laws, educational equity assurance policies, and teacher professional ethics.

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