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Research on the Formation Mechanism and Mitigation Pathway of AI Cognitive Dependence in Education Context

-- A Cognitive Ecology Perspective

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ABSTRACT

The deep integration of generative artificial intelligence (AI) into the field of education expands the cognitive boundaries of subjects and improves cognitive efficiency, while potentially triggering the risk of cognitive dependence and leading to the alienation of educational values. This paper elaborates on the conceptual connotation, alienation manifestations, and potential value crisis of AI cognitive dependence in the educational context. From the perspective of cognitive ecology, a theoretical framework is constructed encompassing four dimensions-cognitive subject, technological intermediary, cognitive environment, and educational crisis-to reveal the systematic structure, dynamics, and evolutionary mechanisms of AI cognitive dependence formation. Feasible pathways to mitigate AI cognitive dependence are proposed from five aspects: technology regulation, subject empowerment, cognitive reshaping, ecological governance, and value reconstruction. Specifically, establish an ethical regulatory system for AI educational applications through data, algorithms, and scenarios; construct an effective "human-in-the-loop" mechanism and refined human-machine cognitive division of labor strategies to strengthen human cognitive dominance; restore the imbalance of cognitive structure through embodied experience enhancement and metacognitive training; implement cognitive diversity protection and ecological niche optimization strategies to maintain the resilience of the cognitive system; reaffirm the unique value of human cognition through value reconstruction and establish a cognitive perspective of "human-computer co-evolution". This paper aims to emphasize the transcendence of educational value rationality over AI instrumental rationality, realize AI's role in promoting "cognitive enhancement rather than replacement" for subjects, construct a new cognitive ecosystem of "human-computer symbiosis", and provide early warnings and practical guidance for ethical governance in the process of educational digitalization.

KEYWORDS

Generative Artificial Intelligence; Cognitive Dependence; Cognitive Ecology; Human-Computer Collaboration; Cognitive Augmentation.

1. INTRODUCTION

The rapid iteration of generative AI technology, especially the deep involvement of large models represented by DeepSeek and ChatGPT in the field of education, is accelerating the fundamental transformation of knowledge views, learning views, curriculum views, and teaching views[1]. Generative AI can simulate human cognitive abilities (such as learning, understanding, reasoning, and decision-making) and exhibit characteristics of cognitive intelligence. Cognitive subjects selectively "outsource" some cognitive tasks to intelligent tools, which to a certain extent saves

cognitive costs, improves cognitive efficiency, and makes up for the deficiencies of their own cognitive abilities[2]. However, while profoundly changing and shaping humans and society, artificial intelligence may also develop into a new external and alienating force[3]. In the application process of generative AI, there may be cognitive traps such as tool substitution for cognition, alienation of cognitive objects, and interference of predictive thinking[4]. Excessive reliance on generative AI tools will affect the subject's ability of independent thinking, judgment, and decision-making, weaken people's ability to solve problems independently, have a negative impact on people's critical thinking, and ultimately lead to the degradation of cognitive abilities that humans should retain[5]. Based on the theoretical framework of cognitive ecology, this paper systematically reveals the alienation manifestations and formation mechanism of AI cognitive dependence in the educational context, and proposes feasible pathways to mitigate AI cognitive dependence. It is helpful to regulate the reasonable use boundary of generative AI technology and explore the dynamic balance relationship between technical empowerment and the essence of education.

2. PROBLEM PROPOSAL: EDUCATIONAL VALUE CRISIS TRIGGERED BY AI COGNITIVE DEPENDENCE

2.1. Connotation Analysis of AI Cognitive Dependence

Technology dependence has long existed in the field of education, mainly referring to people's improper use of technology[6], usually manifested as teachers' and students' functional attachment to technology, using technology as an efficiency intermediary to strengthen operational behaviors. The involvement of generative AI has endowed technology dependence with new characteristics: on the one hand, the powerful content generation capability of generative AI makes teachers and students more dependent on it in links such as knowledge acquisition, problem-solving, and task completion; on the other hand, the interactivity of generative AI further blurs the boundary between "technical tool" and "cognitive partner", and teachers and students may regard it as a cognitive subject that replaces their own thinking. The intensification of this dependence has made the subject shift from technical tool attachment to a deeper level of "cognitive dependence".

In the field of psychology, cognitive dependence is defined as a phenomenon in which individuals' independent cognitive abilities degenerate due to excessive reliance on external cognitive support systems in the process of information processing, decision-making, or problem-solving[7]. Some studies believe that AI cognitive dependence refers to a phenomenon in which humans excessively trust the decision-making output of AI systems and weaken their independent judgment ability in cognitive activities[8]. Zhang Jiacheng et al. believe that AI cognitive dependence is "a psychological state in which individuals excessively rely on the output results of AI systems in the process of cognitive decision-making, leading to the gradual weakening of independent thinking ability, critical judgment, and creative thinking"[9]. An analysis of existing definitions reveals three core elements leading to the formation of AI cognitive dependence: (1) Cognitive trust, that is, the subject is more inclined to believe that AI-generated answers are superior to their own thinking; (2) Sovereignty transfer, manifested as the subject habitually entrusting tasks such as knowledge construction and problem reasoning to AI; (3) Cognitive laziness, the subject's long-term excessive reliance on AI for cognitive activities leads to the degradation of their cognitive abilities. Therefore, we define AI cognitive dependence in the educational context as a phenomenon in which subjects excessively rely on AI to complete cognitive tasks in cognitive activities, resulting in the degradation of their own cognitive abilities, a single thinking mode, and reduced decision-making autonomy. AI cognitive dependence not only includes technical dependence on generative AI but also focuses more on the impact of AI dependence on human cognitive processes and results, as well as the potential threats to educational values.

2.2. Alienation Manifestations of AI Cognitive Dependence

While enhancing the cognitive abilities of educational subjects, generative AI has gradually shaped an implicit dependence structure of subjects from cognitive styles to decision-making behaviors, specifically manifested as weakened cognitive initiative, fragmented cognitive objects, degraded social cognition, solidified cognitive paths, and homogenized cognitive results of subjects.

In terms of cognitive initiative, teachers and students excessively rely on or directly adopt the cognitive frameworks and solutions provided by AI, and gradually degenerate from active knowledge constructors to passive recipients of AI-generated content, leading to the degradation of independent thinking ability. The weakening of the initiative of cognitive subjects will result in a decline in the originality of knowledge, bringing the risk of lack of innovation to learners[10].

In terms of cognitive objects, knowledge acquisition has shifted from the construction of traditional systematic knowledge systems to fragmented and real-time AI-generated content, leading to the "superficialization" of learners' knowledge structures. In particular, the "hallucinations" of large models may lead to errors in AI-generated content, and the unreliability of AI-generated knowledge will lead to negative cognitive risks such as cognitive biases[11].

In terms of social cognition, the involvement of generative AI has changed the traditional subject interaction mode, shifting from the "teacher-student" binary structure to the "teacher-machine-student" ternary structure[12]. This transformation may lead to a reduction in emotional communication and in-depth interaction between cognitive subjects. The erosion of real interpersonal connections by "anthropomorphic" interactions obscures the intersubjectivity contained in the teacher-student interaction process[13].

In terms of cognitive paths, it is mainly manifested as the "prescriptive control" of algorithms over the cognitive process, limiting the flexibility of the subject's thinking. AI systems provide learners with standardized learning paths based on historical data, which may solidify the originally dynamically adjustable cognitive trajectory into an algorithm-oriented one-way channel. The involvement of generative AI not only strengthens specific cognitive paths but also may exclude alternative paths of human independent thinking (such as intuitive thinking, embodied cognition, counterfactual thinking, etc.)[14].

In terms of cognitive results, due to the limitations of AI algorithm logic and training data, the homogenization tendency of generated content is undermining cognitive diversity. The training process of large AI models requires long-term integration and accumulation of data. Once the model training achieves certain results, it will increase the amount of data on the original path rather than making path breakthroughs. Even if learners ask different questions in different contexts, the answers obtained are still highly similar in language logic and content essence, which reflects the singularity of the "thinking" logic formed by instrumental training[15].

2.3. Value Crisis of AI Cognitive Dependence

Generative AI enters the educational field with the vision of "expanding human cognitive boundaries and realizing cognitive enhancement"[16]. However, when learners' technical dependence on generative AI evolves into cognitive dependence, that is, individuals entrust thinking processes such as knowledge acquisition and cognitive construction to intelligent technology, it will trigger an educational value crisis.

Firstly, the gradual dissolution of educational subjectivity. At the teacher level, the standardized teaching design and teaching practice activity plans generated by AI may weaken teachers' creative design capabilities, reducing them to executors of technical tools. Some scholars have pointed out that if students rely on AI to directly obtain answers for a long time, they will lose their awareness and ability of independent thinking, forming subject "disempowerment" under technology dominance,

subject "disability" under technology dependence, subject "disconnection" under technology barriers, and subject "mental decline" under cognitive discretization and fragmentation[17].

Secondly, the instrumental erosion of educational goals. In the intelligent era, educational goals are more inclined to cultivate individuals with critical thinking, creativity, complex problem-solving abilities, and independent personalities. AI cognitive dependence will invisibly turn the educational process towards the worship of technical efficiency. Excessive instrumentalization not only erodes human subject status[18] but also easily leads to regarding technical use as the result of human cognition. For example, the cultivation of core competencies such as students' critical thinking and innovative abilities is simplified into "prompt engineering" training, that is, obtaining more accurate AI output content by optimizing the questioning sentence structure, while the real processes of problem discovery, logical reasoning, and insight formation are seriously marginalized. More importantly, educational dimensions that are difficult to quantitatively evaluate, such as emotional education and aesthetic ability, will be further weakened in the AI-dominated cognitive model.

Thirdly, the systematic disorder of educational ethics. The deep application of generative AI in the field of education has given rise to new types of technical ethical dilemmas, such as algorithmic biases being continuously strengthened through repeated training and feedback loops of data[19], a sharp increase in data leakage risks, and frequent academic integrity issues. This is contrary to the original intention of Reinforcement Learning from Human Feedback (RLHF) to align AI with human intentions. A deeper ethical dilemma lies in the "transfer of cognitive responsibility": when AI-generated content leads to cognitive biases or decision-making errors, learners tend to attribute the responsibility to the technical system rather than reflecting on their own cognitive processes. This responsibility dispersion mechanism weakens individuals' cognitive accountability[20]. In addition, when AI systems intervene in the educational process through "black box" decisions, the criteria for ethical judgment shift from humanistic values to technical utility, and the moral education function of education faces the risk of dissolution..

3. THEORETICAL FRAMEWORK: AN ECOLOGICAL INTERPRETATION OF AI COGNITIVE DEPENDENCE

3.1. Ecological Metaphor of AI Cognitive Dependence

From an ecological perspective, the human cognitive system is similar to a complex biological ecosystem. This system is mainly composed of cognitive subjects (teachers and students), cognitive environments (knowledge resources, technical tools, social culture, etc.), and the interrelationships between subjects and between subjects and the environment, which together shape the structure and function of the cognitive ecosystem. In the cognitive process, subjects continuously interact with the environment, realizing the dynamic balance of the system through resource acquisition, information exchange, and action adjustment, thereby completing cognitive evolution through knowledge transfer and thinking interaction. The specific role and functional positioning of subjects in the cognitive system are similar to the concept of "ecological niche" in ecology, and the path of knowledge transfer and transformation is equivalent to the "food chain". A healthy cognitive ecosystem should maintain an appropriate degree of diversity and complexity, and the flow of energy (individual attention and cognitive resources) and information exchange in the system maintain the stable operation of the system.

Like biological ecosystems, cognitive ecosystems also face the threat of "invasive species", that is, generative AI, with its powerful information processing and content generation capabilities, quickly occupies key nodes in the cognitive ecosystem, breaking the balance of knowledge and energy flow in the system. For example, part of the students' cognitive attention that originally flowed to teachers and textbooks is diverted by AI tools. This change creates a new type of human-machine collaborative cognitive relationship and also leads to a reduction in in-depth interaction between teachers and

students. The invasion of generative AI may lead to "ecological niche replacement", and the subject's excessive dependence on generative AI will cause the degradation of human's own cognitive abilities. The excessive involvement of generative AI brings risks such as reduced cognitive diversity, ecological niche compression, interrupted cognitive energy flow, and weakened system resilience to the cognitive ecosystem in the educational field.

3.2. Theoretical Appropriateness of Cognitive Ecology

As an interdisciplinary research paradigm, cognitive ecology originates from the integration of cognitive science, psychology, and ecology. It focuses on the interrelationship between human cognitive processes and the environment, emphasizing how humans form and develop cognitive abilities in different environments, and how cognitive abilities in turn affect the interaction between learners and the environment. The core view of cognitive ecology holds that the cognitive activities of subjects do not occur in isolation within individuals but are embedded in an ecosystem composed of subjects, tools, and the environment. The products of cognitive activities accumulate not only in the brain but also in the entire cognitive ecosystem[21]. The main contribution of cognitive ecology is to expand the traditional view of cognition as only a logical process to a new understanding of cognition as a biological phenomenon. In the process of its development, it has actively absorbed the viewpoints of social cognitive theory, cognitive offloading theory, and technology dependence theory, and developed new constructs such as embodied cognition, situated cognition, and distributed cognition.

By introducing ecological principles and methods into the field of cognitive research, cognitive ecology provides a new perspective for understanding the phenomenon of AI cognitive dependence in the educational context. Cognition in the educational field is regarded as a dynamic adaptive process, which is not only affected by individual internal psychology but also connected with various factors in the external environment, forming an organic cognitive ecosystem. As an important part of the technical environment, AI profoundly affects the cognitive behaviors and cognitive development of subjects. AI cognitive dependence can be understood as an inconsistent relationship between AI and various cognitive elements in the system caused by the excessive involvement and improper use of AI, leading to system imbalance. For example: excessive reliance on AI's "cognitive outsourcing" will limit the development of learners' critical thinking and independent learning abilities[22]; due to the unknowable "algorithmic black box" between input and output in the deep learning process, the real-time feedback of generative AI ignores the subject's information screening process, leading to the degradation of metacognitive ability; the opacity of AI system decision-making logic may trigger a "cognitive trust crisis"; AI, as an "external technical species", occupies the subject's cognitive ecological niche, leading to the decline of cognitive diversity; excessive reliance on AI may lead to the lack of humanistic care in education. Cognitive ecology not only helps to deeply understand the cognitive process of AI intervening in the educational system, provides an analytical framework for clarifying the formation mechanism of AI cognitive dependence, but also can provide new ideas for solving this educational dilemma.

3.3. Ecological Analysis Framework of AI Cognitive Dependence

Cognitive ecology regards human cognition as a dynamic adaptive system formed by subjects and the environment through technical intermediaries, emphasizing the dynamic interaction between technology, subjects, and the environment. From the theoretical perspective of cognitive ecology, the phenomenon of AI cognitive dependence in the educational field is regarded as a cognitive ecosystem imbalance driven by technical intermediaries. As a new type of technical intermediary, the functional alienation of generative AI is triggering an educational ecological crisis through the path of "technical substitution - cognitive degradation". Specifically, the functional alienation of technical intermediaries is manifested as AI tools shifting from auxiliary cognition to alternative cognition; the cognitive alienation of subjects is reflected in humans' unreflective acceptance of AI-generated

content, forming algorithmic dependence; this alienation further leads to the alienation of educational values (the most prominent is the marginalization of the cultivation of learners' higher-order thinking abilities); in terms of the cognitive environment, it is manifested as the distortion of the human-machine collaborative relationship in the educational system. Therefore, drawing on the framework idea of "subject - tool - object - community" in activity theory[23], this paper constructs a four-dimensional analysis framework of "cognitive subject - technical intermediary - cognitive environment - educational crisis", as shown in Figure 1, aiming to reveal the ecological impact relationship of AI cognitive dependence in the educational field.

4. EVOLUTIONARY DYNAMICS: FORMATION MECHANISM OF AI COGNITIVE DEPENDENCE

4.1. Ecological Structure of AI Cognitive Dependence Formation

The deep embedding of generative AI in the educational field is reshaping the structure of the traditional cognitive ecosystem. The formation of AI cognitive dependence stems from the connection and interaction between technology, subjects, values, and the environment. At the technical level, while natural language interaction brings technical convenience, it also brings the risk of cognitive dimension reduction. When encountering problems, some students first consider asking AI systems directly instead of thinking and solving them by themselves, which to a certain extent leads to the gradual degradation of individuals' independent thinking and problem-solving abilities; although intelligent recommendation seems accurate and efficient, it actually hides the problem of algorithmic dominance, and may cause students to gradually lose their independent choice and judgment abilities in the cognitive process. Learners who long-term select and receive a large amount of homogeneous content in the "information cocoon" generated by AI systems will narrow their information acquisition scope and cognitive vision[24]; AI-generated content has strong "authenticity"[25], which covers up logical faults and factual fallacies, making it difficult for individuals to distinguish the authenticity of information, affecting the accuracy of cognition, and triggering cognitive credulity.

At the cognitive subject level, students excessively rely on AI tools to complete homework, generate papers, and other tasks in the learning process, outsourcing cognitive activities that should be completed by themselves to AI systems. This behavior will prevent students' own cognitive abilities from being exercised and gradually degenerate; generative AI makes virtual interfaces replace real situational experiences, triggering disembodied dilemmas such as the disembodiment of knowledge production, the decontextualization of knowledge learning, and the subjectivity separation of knowledge interaction[26], severing the organic connection between cognition and physical experience, and forming a rupture of individual embodied cognition; students excessively rely on the feedback and suggestions provided by AI, lack reflection and monitoring of their own cognitive processes, leading to the gradual weakening of metacognitive ability; long-term reliance on AI for cognitive interaction leads to reduced social interaction and lack of real interpersonal emotional transmission and interaction effects.

At the educational value level, the excessive involvement of AI strengthens the human-machine relationship and weakens the intersubjectivity between teachers and students, and among students[27]; improper use of AI technology may infringe on learners' privacy and trigger issues such as data security and academic integrity; overemphasizing students' proficient use of AI technology in the teaching process while ignoring the cultivation of students' moral character, emotions, innovative abilities, and other aspects will lead to the alienation of educational goals; the value orientation of AI technology may be contrary to the essence of education, overpursuing efficiency and standardization, and ignoring the humanistic care of education.

At the cognitive environment level, the homogeneity of AI-generated content and the filtering effect of algorithms lead to the gradual homogenization of learners' cognitive styles and cognitive content;

the widespread use of AI tools occupies some cognitive functions originally belonging to teachers and learners, leading to the narrowing of the ecological niche of subjects in the system; AI technology promotes knowledge production and dissemination to be more dependent on data and algorithms, which will change the direction of knowledge flow and the intensity of cognitive energy in the system, resulting in distorted cognitive energy flow; excessive reliance on a single technical path will reduce the fault tolerance of the cognitive system and the resilience of the cognitive ecosystem.

4.2. Dynamic Analysis of AI Cognitive Dependence Formation

From an ecological perspective, the formation of AI cognitive dependence is the result of the synergy of four driving forces: technology-driven, subject choice, social reinforcement, and environmental shaping. (1) Technology-driven. The accurate, real-time, and personalized content generation capabilities of generative AI meet the individual's demand for "efficient cognition". In particular, with the chain of thought of generative AI as an intermediary, through the coupling and mutual construction of human thinking modes and intelligent agent technology logic, a new paradigm of human-machine collaborative knowledge production for knowledge element combination, reasoning, and emergence is realized[28]. The iteration and popularization of generative AI technology make subjects increasingly dependent on AI technology in the cognitive process, gradually forming cognitive dependence. (2) Subject choice. AI technology can quickly and accurately provide a large amount of information and generate solutions, greatly saving individuals' cognitive resources and time costs. This experience of cognitive ease makes individuals more dependent on AI technology and gradually generates cognitive laziness, thereby forming cognitive dependence on AI. (3) Social reinforcement. When subjects are rewarded for using AI technology, they are more inclined to continue using AI, further strengthening their dependence on AI. In addition, reinforcement mechanisms such as policy orientation, cultural identity, and peer effects are also external driving forces for the formation of AI cognitive dependence. (4) Environmental shaping. With the continuous emergence of generative AI platforms and related applications, the proportion of content and information generated by them in learning resources is increasing and easy to obtain, which undoubtedly provides learners with more opportunities to contact and use generative AI, thereby further catalyzing dependent behaviors at the learning environment level.

This paper uses the causal loop analysis method of system dynamics to depict two intrinsic mechanisms of AI cognitive dependence formation in the educational field, namely the self-reinforcement mechanism of path dependence and the risk accumulation mechanism of system imbalance, as shown in Figure 2. The causal loop on the left side of Figure 2 reveals the self-reinforcing process of the deepening of individuals' dependence on AI and the degradation of individuals' cognitive abilities. The delay effect in the loop is reflected in the concealment of the degradation of individuals' cognitive abilities; the causal loop on the right side of Figure 2 reveals the dynamic relationship between AI embedding intensity and cognitive system vulnerability, and the delay effect exacerbates the risk of system imbalance; the two loops do not operate independently but are closely coupled through two variables: AI embedding intensity and AI cognitive dependence degree.

Note: "+" indicates a positive causal relationship, "-" indicates a negative causal relationship, and "~" indicates a delay effect. In a causal loop, if the total number of negative causal chains is even, the loop is a positive causal loop; if the total number of negative causal chains is odd, the loop is a negative causal loop[29].

4.3. Evolutionary Mechanism of AI Cognitive Dependence Formation

From a system evolutionary perspective, the formation of AI cognitive dependence is a complex dynamic process, and its penetration in the educational field goes through four stages: adaptation, competition, symbiosis, and imbalance. This paper analyzes from two dimensions:

Among them, CLI reflects the cognitive processing pressure of subjects on AI tools, which can be measured by indicators such as the proportion of AI-generated content, the replacement rate of cognitive functions, and the degree of dependence on data-driven decision-making; CER is the ability of the system to resist external interference or recover from external interference, which is crucial for understanding the complexity of human cognition and its relationship with the external environment[30]. CER is determined by factors such as system cognitive diversity, redundancy, and recovery ability; the degree of AI cognitive dependence varies in each evolutionary stage, triggering different system responses, and there is a non-linear dynamic relationship between CLI and CER. The two horizontal dashed lines in Figure 3 represent the two critical thresholds of evolutionary transition, and the short dashed curve represents the cognitive ecosystem in the competition stage. If the dynamic balance between CLI and CER is not properly regulated, the system will enter an imbalanced state, increasing the risk of cognitive alienation.

In the adaptation stage, generative AI intervenes in the cognitive process in the form of a "cognitive scaffold", the AI cognitive load intensity is low, and teachers and students' exploration and application of new technologies are limited. AI mainly replaces "mechanical" low-order cognitive tasks, subjects still maintain cognitive autonomy, cognitive niches show initial differentiation, the system remains stable, and the original cognitive model is not impacted; with the deepening of AI technology penetration, the AI cognitive load increases exponentially, and system resilience begins to fluctuate, forming a tension field of human-machine cognitive resource allocation. Generative AI gradually intervenes in higher-order cognitive tasks, and the human-machine cognitive boundary is blurred. If a technical regulatory mechanism is not established in a timely manner, the cognitive system faces the risk of shifting to imbalance due to strengthened path dependence; when the system evolves to the symbiosis stage, the AI cognitive load intensity is in a relatively stable high-level state, and system resilience forms a dynamic balance with AI through self-adjustment. Generative AI provides humans with rich cognitive resources and tools to promote cognitive development, but at the same time, AI technology competes with humans, especially in terms of information processing and decision-making. This competition may lead to humans gradually losing autonomy and creativity in certain cognitive aspects. This symbiotic state of "high load - high resilience" is the adaptive evolution of the educational system to technological penetration; when the AI cognitive load exceeds the system resilience threshold, it will lead to the degradation of the subject's cognitive ability, enhanced thinking laziness, a decrease in the entropy value of system cognitive diversity, a sharp reduction in resilience, and the system becomes more vulnerable. Once the cognitive ecological balance in the educational field is broken, it will trigger systemic risks of cognitive alienation, and effective intervention measures need to be adopted to reconstruct a new cognitive ecosystem.

5. CO-EVOLUTION: MITIGATION PATHWAYS OF AI COGNITIVE DEPENDENCE

When artificial intelligence penetrates into cognitive links such as knowledge production, thinking training, and decision support, the risk of AI cognitive dependence also follows-possibly leading to the degradation of human embodied experience, the weakening of metacognitive ability, and the homogenization crisis of the cognitive system. The key to solving this dilemma lies in building a benign cognitive ecology of human-machine collaboration. It is necessary to design pathways to mitigate AI cognitive dependence from multiple dimensions such as technology regulation, subject empowerment, cognitive reshaping, ecological governance, and value reconstruction, so as to realize the two-way empowerment, co-evolution, and symbiotic development of the human-machine cognitive system.

5.1. Technology Regulation: Constructing Ethical Norms for AI Educational Applications

Technology regulation is a governance model that guides or restricts user behavior through preset technical design, algorithm logic, or system architecture[31]. Specifically, it can be designed through three levels: data, algorithms, and application scenarios. At the data level, first, formulate standard processes for the collection and processing of educational data. Clarify the scope, methods, and requirements of data collection, follow the principle of minimum necessity, only collect data directly related to educational goals, and formulate unified data processing specifications. Second, ensure the traceability of the data sources for educational AI model training. Endow each piece of data with a unique identifier and a complete operation log through blockchain technology to realize the full-process traceability of data from collection, processing to application[32]. Third, establish a sensitive data screening mechanism. Adopt differential privacy technology to desensitize data involving students' identities, mental health, family backgrounds, etc.[33]. Finally, establish a data privacy and security protection mechanism, and use encryption technology for data storage and transmission to ensure the security of user data throughout the entire application life cycle.

At the algorithm level, the key lies in avoiding algorithmic biases and realizing the transparency of algorithm logic and decision-making processes. For example: strictly screen and preprocess training data to ensure the diversity and representativeness of data, and avoid biases existing in the data set being transmitted to the algorithm; use explainable AI technology to convert AI decision-making logic into human-understandable rules, and present the AI decision-making logic chain through visualization technology to make its decision-making process more intuitive and understandable, thereby enhancing users' trust in the AI system[34].

At the scenario level, it is necessary to establish a dynamic monitoring mechanism for AI system applications, and real-time track the application of generative AI in educational scenarios, including multi-dimensional data such as students' usage frequency, usage duration, usage purposes, and the quality of AI output content, so as to promptly identify potential cognitive risks. At the same time, it is also necessary to establish an early warning mechanism to real-time monitor key indicators such as the subject's cognitive outsourcing rate, thinking convergence degree, and cognitive diversity attenuation index, and trigger function restrictions when exceeding the safety threshold, thereby enhancing the controllability of AI educational applications. Some scholars have proposed "establishing an access review system for generative AI products and implementing a dynamic supervision method of black, gray, and white lists"[35].

5.2. Subject Empowerment: Enhancing the Subject's Ability to Control Technology

The core of reconstructing human dominant position in cognitive activities lies in activating the subject's subjective initiative in human-machine interaction, enabling it to shift from "passive adaptation" to AI technology to "active control" and possess wisdom beyond AI. First, cultivate the subject's AI literacy from the aspects of "technical understanding, critical application, and ethical reflection"[36]. Teachers and students need to understand the basic principles, technical characteristics, ability boundaries, and ethical risks (such as data bias, hallucination problems) of generative AI; train students to cross-verify with multi-source information to verify the credibility of AI-generated content; emphasize the academic integrity issues in AI use and avoid uncritically accepting AI outputs; guide students to examine the responsibility attribution and moral boundaries in the application of AI technology. Second, construct an effective "human-in-the-loop" collaboration mechanism. Cognitive subjects should fully participate in the entire workflow of generative AI, playing an active role from problem formulation and task planning to result review. Third, refine the human-machine cognitive division of labor strategy. Clarify the cognitive division of labor in human-machine collaboration based on the principle of complementary advantages between human cognition and AI[37].

5.3. Cognitive Reshaping: Restoring the Subject's Embodied Experience and Metacognition

Cognitive reshaping refers to the process of intervening in and guiding the individual's cognitive process to repair the imbalance of cognitive structure caused by technology dependence and restore or enhance the subject's cognitive ability. Improper use of intelligent technology will cause learners to experience alienation phenomena such as "fragmented physical experience, standardized form, disembedded communication, and deviated values" in cognitive activities[38]. Restoring embodied experience requires reconstructing the connection between cognition and the body through multi-sensory learning activities. In the teaching process, embodied experience can be restored through activity designs that strengthen physical participation, multi-sensory integration methods, and emotional concrete expression. The real-time feedback mechanism of generative AI and the provided "standard answers" are likely to make learners form thinking laziness. They may no longer take the initiative to reflect on and adjust their own cognitive processes, resulting in the degradation of metacognitive ability. Through metacognitive training, students are allowed to monitor their own thinking processes in the process of completing tasks. For example, require students to record their thinking paths with the help of AI, regularly evaluate their own degree of dependence on AI, and form self-regulation ability.

5.4. Ecological Governance: Maintaining the Diversity and Resilience of the Cognitive System

Ecological governance aims to construct a technology-for-good governance system through cognitive diversity protection mechanisms, ecological niche optimization strategies, and system resilience enhancement pathways, so as to maintain the dynamic balance of the cognitive system. In terms of cognitive diversity protection, when using large AI models to assist cognition, encourage multi-model competition to avoid a single model monopolizing knowledge production; use the redundancy theory in ecology to establish alternative cognitive paths not supported by AI, maintaining the coexistence of multiple cognitive styles. In terms of ecological niche optimization, the auxiliary role of AI should be clarified, the boundaries of AI use should be divided, and it should be confirmed that core cognitive abilities (value judgment, creativity, complex problem-solving) are dominated by subjects; limit the proportion of AI in cognitive process links, and strengthen the subject's function of content screening and value guidance; through "anti-algorithm" means such as forcibly retaining thinking space and limiting AI decision-making weight, realize the return of educational evaluation dominance from algorithms to human cognitive abilities. In addition, based on the principles of heterogeneous symbiosis (co-evolution of different cognitive subjects, cognitive tools, and cognitive strategies), dynamic balance (maintaining the balance between technical empowerment and cognitive autonomy through feedback regulation), and adaptive governance, construct a cognitive ecological evaluation system to enhance the resilience of the cognitive system, enabling it to maintain stability in the face of technological changes.

5.5. Value Reconstruction: Reaffirmation of the Uniqueness of Human Cognition

AI technology is not inherently endowed with cognitive abilities but acquires relevant abilities through human design and innovation. It is essentially "created" and "instrumental", and cannot reverse the natural attributes of human innate cognition. Its intervention in the educational system requires the correction of natural values[39]. Compared with AI technology, human cognition has uniqueness in ambiguity tolerance, value judgment, and imagination. Value reconstruction is not technological exclusion, but by clarifying the irreplaceability of human cognition, setting ethical boundaries for human-machine collaborative cognition, and better realizing the complementary advantages of humans and machines. The relationship between AI and humans is not only "instrumental use" or "functional substitution" but an "auxiliary support" relationship between the

two, with unique collaborative characteristics: machines enhance human abilities through information processing and decision support, while humans retain control over key decisions and exert creativity and judgment[40]. To promote the cognitive subject's active transformation of AI, the ethical coordinates can be reconstructed from aspects such as strengthening emotional connection, calibrating values, and reconstructing humanistic courses.

6. CONCLUSION

The research on AI cognitive dependence in the educational field not only focuses on the use of tools themselves but also emphasizes the reconstruction effect of technical intermediaries on the cognitive system-it may lead to the "compensatory degradation" of educational subjects' cognitive abilities and the attenuation of cognitive system diversity by changing information screening mechanisms, reshaping knowledge production processes, and intervening in cognitive decisions. The introduction of cognitive ecology regards cognitive activities in the educational field as a dynamically adaptive complex system, thereby more comprehensively analyzing the long-term impact of AI technology intervention. The formation of AI cognitive dependence is a complex systematic process involving the interaction of multiple factors such as technology, subjects, environment, and values, and its evolution is driven by multiple forces including technology-driven, subject choice, social reinforcement, and environmental shaping. AI cognitive dependence is a warning caused by the imbalance of human-machine relations, and its essence is the usurpation of educational value rationality by technical instrumental rationality. Following the dual logic of "people-oriented" and "intelligence for good", this paper proposes mitigation pathways from five dimensions: "technology regulation, subject empowerment, cognitive reshaping, ecological governance, and value reconstruction", aiming to construct a new cognitive paradigm of "human-machine co-evolution". The ideal vision for the future is that AI becomes a "partner" to expand human cognitive boundaries, while humans maintain their core position as the source of meaning construction and value judgment, making AI a "catalyst" to stimulate human thinking potential, and enabling human cognition to achieve real evolution in human-machine collaboration.

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