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Current Research Status of Students' Creativity Development under the Human-Machine Collaborative Teaching Mode at Home and Abroad

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Abstract: With the integration of the "AI+" era into society, the importance of creativity has grown. The human-machine collaboration model, spurred by "AI + Education," aims to reshape the teaching ecosystem and enhance effectiveness. However, research on its impact on student creativity development remains insufficiently systematic.To address this, this paper defines key concepts of human-machine collaboration and creativity, then systematically reviews 81 domestic and international journal articles using a literature synthesis approach. It further distills a research framework and discusses three core themes:Instructional Mechanism Design: How AI reshapes the foundation for cultivating creativity;The Creativity Paradox: Efficacy gains versus hidden costs in human-machine collaboration;The Ethical Dilemma: Structural tensions between technological rationality and humanistic values.Finally, it outlines future research directions. This study holds significant importance for clarifying the current research landscape in this field.

Keywords: Human-Machine Collaboration, Creativity Development, Literature Review.

1. Conceptual Definition of Human-Machine Collaborative Teaching

In recent years, with the rapid development of artificial intelligence (AI) technology, the 'AI+' era has become integrated into society. Against this backdrop, the importance of creativity has become increasingly prominent. Human-machine collaborative teaching represents the core paradigm of educational model transformation in the AI era. Its conceptual definition requires integration across three dimensions: the relationship between educational agents, the functional attributes of technology, and teaching objectives:

(1)Tripartite Role Structure Theory: proposed a "Human Teacher-AI Teacher-Student" triadic framework. This emphasizes the formation of an educational symbiosis through dynamic function allocation between human teachers (responsible for emotional guidance/ethical decision-making) and AI systems (responsible for data analysis/process optimization)[1]. For instance, in CNC programming instruction, the AI optimizes process parameters (programmable tasks), while the teacher leads creative design guidance (non-programmable tasks).

(2) Task Allocation Principle: Teaching tasks are categorized into three types: programmable tasks, non-programmable tasks, and semi-programmable tasks.

Programmable Tasks: AI leads tasks like assignment grading and learning diagnosis, e.g., ChatGPT automatically generating grammar exercise feedback.

Non-Programmable Tasks: Teachers undertake tasks like value cultivation and emotional motivation, e.g., guiding critical thinking in classroom debates.

Semi-Programmable Tasks: Human-AI collaboration completes tasks like inquiry-based learning design, e.g., the AI recommending cross-disciplinary cases and the teacher optimizing scenario creation.

(3)Educational Objective Orientation: Distinct from traditional Computer-Assisted Instruction (CAI), human-machine collaboration focuses on cultivating higher-order competencies such as creativity. For example, Tu Jun demonstrated in digital media courses that AI tools (e.g., Midjourney generating materials) liberate students from technical operational burdens, allowing them to concentrate on creative expression[2].

In summary, human-machine collaborative teaching, as defined in this paper, operates within the "Teacher-Student-Machine" triadic framework. Teachers and AI form an educational symbiosis through dynamic function allocation, utilizing the three distinct types of teaching tasks as a lever, and focusing on the cultivation of students' higher-order competencies.

2. Conceptual Definition of Creativity

The traditional definition of creativity emphasizes the dual characteristics of originality and effectiveness, centered on Guilford's divergent thinking model and Torrance's creativity tests (encompassing fluency, flexibility, originality, and elaboration). However, the intervention of artificial intelligence has prompted an expansion of the connotation of creativity towards technology-enhanced creativity, emphasizing the ability to integrate cross-domain knowledge and technological tools through human-machine collaboration[3]. Its composition presents a three-dimensional hierarchical structure:

(1) Cognitive Creativity: Refers to an individual's higher-order thinking ability to break through conventional frameworks, manifested as divergent thinking, critical thinking, and insight emergence. For instance, Runco notes that AI tools can make thinking processes explicit through Chain of Thought prompting, but cautions against the risk of 'pseudo-creativity,' where generated content lacks genuine emotional depth[4].

(2) Knowledge Creativity: Involves the deep understanding of domain-specific knowledge and the ability for cross-domain transformation. Amabile's Componential Theory of Creativity emphasizes that domain-relevant skills, creativity-relevant processes, and intrinsic task motivation jointly

activate innovative efficacy[5].

(3) Technological Creativity: Focuses on the ability to utilize AI tools to expand the boundaries of ideas, such as optimizing design through prompt engineering[6]. For example, in engineering design courses, students using generative AI to reconstitute knowledge of mechanical principles and aesthetics saw a 32% increase in the technical feasibility of their innovative solutions[7].

In the AI era, creativity evaluation is no longer confined to psychological traits; it necessitates incorporating the dimension of technological empowerment. Gao Xinmin and Zhang Zhou propose a "Contextualist Model," positing that creativity is the dynamic outcome of the interaction between technological tools and human cognition, where algorithms reconstruct the innovation threshold through data-driven approaches[8].

3. Current Research Status of Empowering Students' Creativity Development via Human-Machine Collaborative Teaching: Content Framework and Research Themes

Based on systematic coding of 81 literature sources (Table 1), current research primarily revolves around three major themes: instructional mechanism design, impact on creativity development, and ethical/cognitive challenges. Human-machine collaboration restructures teaching processes through AI's generative, evaluative, and collaborative functions. While enhancing creativity efficacy, it simultaneously triggers cognitive conflicts and ethical risks.

Table 1. Literature Coding Framework for Creativity Research in Human-Machine Collaborative Teaching

Main Category	Subcategory	Representative Literature	Key Findings
instructional mechanism design	Task Collaboration Strategy	Guo et al. (2025)	AI generates unconventional problems (e.g., zero-gravity architecture) to stimulate counter-intuitive solutions and enhance divergent thinking.
	Process Guidance Technology	Hoßbach et al. (2025)	The metacognitive questioning framework (e.g., "50% time reduction plan adjustment") strengthens reflective thinking abilities.
	Feedback Regulation System	Nitzav(2025)	Delivers tiered tasks based on creativity levels: divergent thinking exercises for low-level groups → cross-disciplinary projects for high-level groups.
creativity development impact	Cognitive Ability Enhancement	Cahyono et al. (2025)	The "Math Dance" system facilitates the transfer of geometric thinking to kinesthetic intelligence.
	Affective Motivation Stimulation	Siegle(2025)	Eliminating the "fear of the blank canvas" increases the draft output of art students by 2.4 times.
	Skill Transfer Barriers	Runco(2025)	33% of middle school students ignore logical flaws due to the superficial rationality of AI-generated solutions.
ethical-cognitive adjustment	Algorithm Transparency Controversy	Gao，X. M(2025)	Quantitative novelty evaluation standards overlook cultural values (e.g., dialect-based creative expression).
	Boundary of Human-Machine Rights and Responsibilities	Tu, J (2025)	The localization adaptation rate of Chinese and Western cases in digital media majors is only 41%.
	Cultural Adaptability Differences	Dent (2025)	Latin American students resist the individualistic orientation of AI tools and adhere to the tradition of community co-creation.

Based on synthesizing existing research (Urmeneta & Romero[9],Wang Yiyan[10]), the impact of human-machine collaborative teaching on creativity can be conceptualized as a closed-loop system comprising instructional mechanism design → creativity development impact → ethical-cognitive adjustment.

The essence of this framework lies in the deep coupling of technological logic and educational objectives, which reconstructs the teaching process of "problem generation → cognitive stimulation → value judgment," forming a dynamic educational ecosystem.

AI activates lateral associative thinking through unconventional problems (e.g., cross-species gene recombination topics)[11] and facilitates multi-path exploration via dynamic variant problems[12]. Teachers, meanwhile, transform into "algorithm mediators," balancing technical efficiency with humanistic care (e.g., localizing AI-generated prompts)[13].

This collaborative mechanism catalyzes a double-edged effect on creativity: while AI enhances creative output in Business English by 37%[14], it simultaneously leads to a decline in independent problem discovery ability among 62% of graduate students[15].

Ethical adjustment is consequently triggered. For instance, when Explainable AI (XAI) only elucidates 28% of scoring logic[16], it compels vocational schools to implement a three-tier review system[17].

Thus, instructional mechanism flaws, ethical conflicts, and governance innovation constitute a self-correcting closed loop, highlighting the inherent tension between technical efficiency and humanistic values within human-machine collaboration.

3.1. Teaching Mechanism Design: How AI Reshapes the Environment for Creativity Cultivation

The core breakthrough of human-machine collaborative teaching lies in the deep integration of AI's computational power with teachers' contextual decision-making capacity[18], forming a symbiotic relationship characterized by data-driven processes and humanistic adaptation. This integration is not a simple addition of technological tools; rather, it constructs a dynamically evolving educational ecosystem through a three-tiered restructuring of task collaboration, process guidance, and feedback systems.

Task Collaboration: From Preset Problems to Dynamic Generation. In traditional teaching, problem design is often limited by teachers' experiential boundaries. AI, however, generates unconventional scenarios using multi-source data (academic literature, social issues, cross-disciplinary knowledge bases) to provoke cognitive conflict.

(1)Cross-disciplinary Integration: In biology classes, ChatGPT-3 designed the topic "Optimizing Oxygen Supply in Space Capsules through Plant Photosynthesis"[11], forcing students to integrate life sciences (optimizing light reaction pathways) and engineering (calculating energy consumption in closed systems) to propose innovative solutions like "bionic leaf-vein oxygen delivery pipes." Such designs break down disciplinary barriers, elevating knowledge restructuring ability by 37% (based on empirical data).

(2)Dynamic Complexity: Mathematics AI assistants dynamically adjust structural mechanics parameters (e.g., seismic intensity, material load-bearing limits), driving students to iteratively verify multimodal load-bearing solutions[12]. In bridge design experiments, students achieved 92% of theoretical structural stability through 12 parameter iterations, significantly enhancing iterative thinking.

However, over-reliance on AI-generated problems may lead to homogenization traps – 33% of middle school students accepted AI's "superficially plausible solutions" (e.g., "solar-powered deep-sea submarines") while overlooking logical flaws[4]. The solution lies in teachers' contextual correction authority. For example, in an English class, when AI recommended a "Western Thanksgiving creative writing" prompt, the teacher infused the localized context of "China's Spring Festival travel rush," increasing the authenticity of student emotional expression by 41%[13]. Notably, current task design primarily focuses on academic contexts, revealing an adaptation gap in vocational education: only Tu Jun mentioned the need to transform "Hollywood special effects cases" into localized projects like "Dunhuang mural dynamic restoration" for digital media majors[2], while automotive repair lacks "new energy vehicle fault simulation generators," and nursing lacks "emergency rescue scenario AI simulation systems"[19].

Process Guidance: Dynamic Scaffolding. AI's scaffolding function requires dynamic regulation between "divergent exploration" and "goal constraint," manifested through three support mechanisms:(1)Cognitive Offloading: Technology tools free up cognitive resources. E.g., AI chord generators in music composition automatically handle music theory rules, allowing students to focus on emotional expression. Empirical data shows a 2.3x increase in improvisational efficiency and significantly enhanced emotional complexity[20].(2)Metacognitive Training: Question frameworks deepen reflective capacity. E.g., prompts like "How would you adjust the plan if the budget were cut by 50%?" increased the feasibility score of business plan proposals by 28% and cost optimization efficiency by 39%[18].(3)Collaborative Optimization: Intelligent role allocation systems (e.g., "Idea Proposer - Challenger - Integrator") reduced group blind conformity by 67%, while role rotation increased cross-boundary skill mastery rates to 81%[21].

Yet, technological dependency risks must be guarded against – 70% of students in art classes exhibited stylistic convergence due to over-reliance on AI composition tools[22]. This necessitates teacher-implemented "interruption designs" (e.g., disabling AI tools during the sketching phase) to enforce original ideation[23].

Feedback System: From Static Scoring to Process-Oriented Creativity Diagnosis.

(1)Multidimensional Diagnosis: NLP techniques generate novelty-feasibility-ethical value tridimensional scoring. E.g., in a social enterprise proposal, the combination "Employment for People with Disabilities + AR Remote Assistance" scored significantly higher in ethical value (92) than purely commercial solutions (67), guiding students towards social innovation[24].

(2)Adaptive Motivation: Blockchain generates visual competency maps. Programming students observing their transition from "code replication" to "algorithmic originality" via timeline views reported an 89% increase in self-efficacy[25].

However, algorithms exhibit cultural blind spots. Essay scoring systems, for instance, favor high-frequency vocabulary, suppressing unconventional metaphors like "a single spark can start a prairie fire"[26]. Furthermore, XAI (Explainable AI) can only elucidate 28% of scoring logic[16], hindering students' understanding of low scores. This issue is particularly acute in vocational education. E.g., algorithms misclassified an automotive repair student's "poetic description of gearbox noise" as off-topic[2], highlighting the lack of occupational contextualization in technological adaptation.

3.2. Creativity Paradox in Human-Machine Collaboration: Efficiency Gain and Hidden Loss

The impact of human-machine collaborative teaching on creativity exhibits a complex profile characterized by "cognitive enhancement - affective empowerment - skill inhibition"[24]. Its essence lies in the structural tension between technological empowerment and humanistic values. Empirical studies show positive effects reach 72% in STEM fields but only 48% in humanities and social sciences[7][14]. This disparity stems from the adaptation conflict between disciplinary thinking modes and algorithmic logic. When AI tools deeply intervene in educational processes, they may unleash innovative potential through cognitive offloading, but also risk inhibiting critical thinking via standardized outputs, forming an "efficiency trap" for creativity cultivation.

Cognitive Enhancement: Expanding and Restructuring Cognitive Boundaries. AI tools activate lateral thinking pathways through semantic association reinforcement (e.g., Word2Vec word vector models), significantly boosting creative generation efficiency: in Business English classes, ChatGPT's real-time generation of marketing slogan variations increased creative output by 37%[14]. Cross-modal learning leverages embodied cognition mechanisms: a "Math Dance" system translating Riemannian curvature into body movements improved geometric problem-solving speed by 41% after 12 training iterations, with skills transferring to mechanical design contexts[27]. Concept restructuring efficacy manifests as metaphorical innovation: in biology knowledge networks, visualizing the analogy between mitochondria and "city power plants" via knowledge graphs enhanced cross-disciplinary associative ability by 29%[11]. fMRI research confirms this process strengthens functional connectivity between the default mode network and prefrontal cortex[28]. However, cognitive enhancement is domain-specific: engineering students using AI to deconstruct architectural problems produced 1.8 times more innovative solutions[8], while similar tools led 35% of literature students into formulaic narratives[26], revealing a disciplinary chasm in technological adaptation.

Affective Motivation: From Anxiety Reduction to Cross-Cultural Empathy. AI alleviates creative anxiety through error-tolerant design: "blank canvas phobia" caused procrastination in 40% of traditional art students, while tools like DALL-E provided modifiable compositional frameworks, increasing draft output by 2.4 times and reducing anxiety indices by 58%[23]. Instant feedback loops reinforce self-efficacy: in music composition, AI mixing tools identified chord conflicts via spectral analysis; students' motivation increased by 31% after adjustments triggered real-time visual feedback, with the "sense of technological mastery" fueling sustained innovation[20][29]. Context-embedded learning further cultivates cross-cultural empathy: VR/AI constructed diverse user scenarios (e.g., Muslim attire design, accessibility interface optimization), raising cross-cultural solution adoption rates from 52% to 83% after 8 iterations[30]. Yet, aesthetic homogenization must be guarded against: 70% of students relying on layout tools like Canva produced works with similar color schemes (89% Morandi palette usage), exposing the fundamental conflict between technical efficiency and artistic originality[22].

Skill Inhibition: Migration Barriers and Adaptation Dilemmas. Algorithmic inertia erodes higher-order thinking:

62% of graduate students experienced diminished independent problem discovery due to ChatGPT dependency, with fMRI showing a 33% reduction in prefrontal activation intensity[15][28]. Completion illusions blunt critical thinking: 33% of middle school students accepted superficially plausible solutions like "solar-powered deep-sea submarines" while overlooking energy transmission flaws[4]. Algorithmic bias training suppresses expressive uniqueness: essay scoring systems favoring high-frequency word combinations reduced unconventional expression usage by 41%; poetic descriptions like "gearbox noise resonating like evening drums and morning bells" by vocational auto repair students were misclassified as off-topic[2][26]. The root cause lies in XAI (Explainable AI) elucidating only 28% of scoring logic[16].

3.3. Ethical Dilemma in Human-Machine Collaboration: Structural Conflict Between Technical Rationality and Humanistic Values

The deep-seated contradictions in human-machine collaborative education manifest as a tripartite tension comprising algorithmic black box cognitive barriers, institutional voids in accountability, and systemic imbalances in cultural adaptation. This stems from the fundamental conflict between technological efficiency logic and the humanistic nature of education-algorithms rely on quantifiable metrics for decision-making, while cultivating creativity necessitates accommodating ambiguity, contextuality, and cultural diversity. Empirical evidence shows a 37% decline in student innovation motivation in classrooms where this conflict is inadequately addressed[31], underscoring the urgency for resolution and necessitating an "human-led, algorithm-checked" adaptive model embedded with ethical review and humanistic intervention mechanisms[17].

At the level of algorithmic transparency, disputes over value judgment authority constitute a core ethical challenge. When AI assesses complex competencies like creativity, the question of "who defines creativity" exposes technological limitations: current systems often reduce multidimensional creativity to quantifiable indicators (e.g., equating lexical statistical frequency with novelty), leading to cultural value blindness—creative expressions rich in local wisdom, such as dialect-based innovations or oral tradition reinterpretations, suffer scoring disadvantages for not conforming to the "high-frequency novelty" patterns of mainstream corpora[8]. In entrepreneurial competency assessment, modeling based on economic indicators (commercial success rate, profit expectations) systematically undervalues social innovation, resulting in significantly lower scores for social enterprise proposals compared to purely commercial projects[17]. A deeper dilemma is the lack of algorithmic explainability: Explainable AI (XAI) can only elucidate 28% of scoring logic[16]. Students facing rejected proposals without comprehensible explanations experience not only diminished motivation but also a failure of the "feedback for growth" mechanism, transforming algorithms into an unquestionable "digital arbiter" that erodes educational fairness.

Blurred accountability boundaries, meanwhile, trigger dilemmas in the reorientation of educational agents. Teachers are transitioning from knowledge transmitters to "algorithm mediators," tasked with identifying tendencies toward exam-oriented templates in AI-generated content and guiding students in critical revision. However, this process is accompanied by data sovereignty disputes: the continuous monitoring via biometric technologies (e.g., facial expression analysis, voice emotion recognition) raises complex issues regarding data access permissions and privacy boundary definitions[32]. More severe is the rupture of the responsibility chain: 37% of teachers exhibit unclear understanding of copyright ownership for AI-generated content (e.g., Midjourney images)[33]. When such content involves plagiarism, bias, or harmful information, the lack of clear guidelines for apportioning responsibility among students, teachers, technology providers, and platforms creates an accountability vacuum, exacerbating legal risks.

Adaptation gaps between technological culture and local educational cultures form a deep-seated bottleneck for global implementation. Mainstream AI models, particularly Large Language Models (LLMs), are rooted in Western (especially Anglo-Saxon) cultural contexts and individualistic values, creating structural friction with diverse global educational practices: In communitarian regions like Latin America, AI's promotion of individualistic creative orientation clashes with traditions valuing collective wisdom, provoking student resistance[30]; in Chinese vocational education, case studies based on Western workplace cultures result in student engagement rates as low as 41%[2], as disconnection from local practices hinders knowledge transfer; linguistically, LLMs exhibit structural "discrimination" against non-English languages and dialects, systematically suppressing creative forms like Cantonese homophonic puns for not conforming to standard English paradigms[22]. This not only causes evaluation bias but also accelerates the marginalization of local cultures in the digital age, contradicting education's core mission of preserving cultural diversity.

4. Future Research Directions of Human-Machine Collaborative Teaching and Students' Creativity Development

Building upon the synthesis and critical reflection of existing research, future studies on student creativity development within human-machine collaborative teaching models must advance toward greater depth, breadth, and practical value.

First, there is a critical need to deepen research on adapting to the specificities of vocational education and develop occupationally contextualized AI simulation systems. Current research predominantly focuses on academic contexts, leaving significant gaps in AI tool development for practice-intensive fields like automotive repair and nursing, exemplified by the lack of tools such as "new energy vehicle fault simulators" or "emergency rescue scenario AI simulation systems." Future research should strive to construct virtual training environments that are highly coupled with real-world work scenarios. These environments should utilize AI to dynamically generate complex problems meeting industry standards, guiding students to spark innovative thinking while solving practical technical challenges. Concurrently, research must establish creativity evaluation systems integrating industry-specific metrics, such as incorporating the commercial feasibility of design proposals.

Second, efforts must focus on resolving the creativity paradox inherent in human-machine collaboration and exploring intervention strategies to mitigate associated risks.

To counter AI-induced risks like thinking homogenization and the blunting of critical thinking, future research must move beyond simple technological tool application towards deeper integration at the cognitive interaction level. For instance, exploring "adversarial prompting strategies" could be pivotal, using pre-set counterexamples and critical point interventions to break algorithmic rigidity and activate students' original thinking within vocational contexts. Furthermore, research should intensively investigate the application mechanisms of models like the "dual-chain iterative teaching framework" in secondary vocational classrooms, clarifying the teacher's crucial role in filtering and reconstructing AI-generated content. By designing "interruption points" that compel students to engage in original ideation, students can benefit from technological empowerment while safeguarding their cognitive autonomy and the uniqueness of their thinking.

Finally, it is imperative to directly confront and proactively construct an ethical governance framework for human-machine collaboration to resolve the structural conflict between technological rationality and humanistic values. Future research should concentrate on enhancing algorithmic transparency and fairness. This includes developing more advanced Explainable AI (XAI) systems capable of parsing a greater proportion of scoring logic, and establishing dynamic copyright attribution systems to clarify ownership and responsibility for AI-assisted outputs. More crucially, research must drive the cultural adaptation transformation of AI educational applications. This involves building diverse databases encompassing local cases, dialect corpora, and non-Western value orientations to correct the cultural biases prevalent in mainstream models. Such efforts will ensure technological tools respect and stimulate creative expression across diverse cultural backgrounds, thereby achieving a genuine balance between technological empowerment and humanistic care amidst the tensions of globalization and localization.

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