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Article

Research on the Development Path of College Students' English Writing Competence from the Perspective of Human-Machine Collaboration: An Exploratory Application Based on Generative Artificial Intelligence

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Abstract: This study investigates the application of Generative Artificial Intelligence (GAI) in enhancing Chinese college students' English writing competence, based on a tri-dimensional theoretical framework integrating human-machine collaboration, second language acquisition and writing cognitive process. It addresses the dual challenges posed by GAI's inherent limitations and students' intrinsic writing deficiencies and clarifies the four-dimensional connotation of English writing competence development path (cognitive process, strategy use, metacognitive regulation, human-machine interaction mechanism). A questionnaire survey (supplemented by 6 semi-structured interviews) was conducted among 200 college students from 12 universities in China, utilizing a self-designed Questionnaire on the Current Status of College Students' Use of Generative AI in English Writing. The findings indicate that ChatGPT was the most widely used GAI tool, framework construction prior to writing was the primary application scenario, and 92.0% of students expressed willingness to continue using GAI for writing assistance. Based on these empirical insights and exploratory application cases in college English writing classrooms, a three-stage competence enhancement strategy system was constructed: (1) Pre-writing: Students independently develop writing outlines before leveraging GAI for supplementary inspiration, with teachers providing evaluation criteria for GAI to reference; (2) While-writing: Students complete first drafts independently, then utilize GAI for targeted revision, while teachers guide students in discerning the validity of GAI-generated feedback; (3) Post-writing: Students submit revision reports and reflect on their writing processes, with teachers establishing electronic portfolios for students based on human-machine interaction records. This study demonstrates that GAI application, when scientifically guided, can significantly improve students' writing logic and vocabulary application. Meanwhile, it conducts an in-depth critical reflection on GAI's ethical risks, academic integrity issues and teaching backlash. The proposed strategy system aims to achieve the organic integration of "technology empowerment" and "competence-based education", providing practical implications for advancing English writing instruction reform and the deep integration of GAI with foreign language education.

Keywords: Generative Artificial Intelligence (GAI); Chinese College Students; English Writing Competence; Human-Machine Collaboration; Intelligent Writing Assistance

1. Introduction

With the successful convening of the 2025 World Digital Education Conference, the integrated application of Generative Artificial Intelligence (GAI) in the field of education has emerged as a focal issue of common concern among global academics, educational policymakers, and frontline teaching practitioners. Against the backdrop of the deep interweaving of globalization and digitalization, college English education, as a core component of the higher education system, aims not only to disseminate linguistic knowledge but also to cultivate compound talents with cross-cultural communication competence who can engage in international academic and social exchanges. As a core dimension of cross-cultural communication competence, English writing competence is essential for college students to convey thoughts, viewpoints and academic insights clearly, accurately and coherently, and to hone logical reasoning, critical analysis and innovative thinking through writing practice, laying a solid foundation for lifelong learning and career development.

Endowed with powerful natural language processing and multimodal content generation capabilities, GAI breaks through the bottlenecks of limited resource access and delayed feedback in traditional English writing teaching, providing an unprecedented opportunity for the innovation of teaching models and the optimization of learning paths for English writing competence development. Existing empirical studies have confirmed the positive effects of GAI in improving English writing competence (Tsai et al., 2024). However, the application of GAI in English writing is a “double-edged sword”: while it empowers teaching and learning, it also brings multiple challenges such as academic integrity risks, technical dependence, ethical dilemmas and teaching backlash. In the absence of scientific guidance, these challenges may exacerbate college students’ inherent deficiencies in English writing, such as insufficient vocabulary reserves and disorganized text structure, and even hinder the cultivation of their higher-order thinking abilities.

1.1 Theoretical Framework and Concept Connotation

This study constructs a tri-dimensional theoretical framework for GAI-assisted English writing competence development (Figure 1), taking human-machine collaboration theory as the core, integrating second language acquisition theory (Contrastive Analysis Hypothesis, Input Hypothesis) and writing cognitive process theory (planning-drafting-revising). Human-machine collaboration theory clarifies the interactive relationship between students (subject), GAI (auxiliary tool) and teachers (guide) in the writing process; second language acquisition theory provides a theoretical basis for explaining GAI’s role in optimizing language input and reducing negative mother tongue transfer; writing cognitive process theory divides the writing process into pre-writing, while-writing and post-writing, which is the structural basis for constructing the three-stage enhancement strategy.

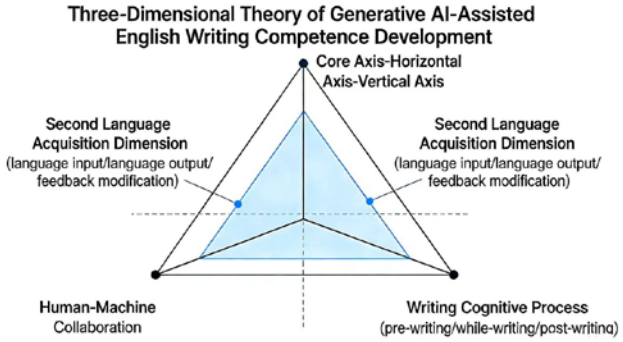

Figure 1. Tri-dimensional Theoretical Framework of GAI-assisted English Writing Competence Development

On this basis, this study clearly defines the four-dimensional connotation of English writing competence development path (Table 1), which is no longer a broad concept but a structured system covering cognitive,

strategic, metacognitive and interactive dimensions: (1) Cognitive process: the improvement of writing conception, logical construction and content expression abilities in the process of using GAI; (2) Strategy use: the mastery and flexible application of GAI-assisted writing strategies such as outline construction, error correction and resource supplementation; (3) Metacognitive regulation: the ability to monitor, evaluate and reflect on one's own writing process and GAI application effect; (4) Human-machine interaction mechanism: the formation of a scientific interaction mode of "student autonomy first, GAI supplementary empowerment" and the mastery of efficient human-machine interaction skills such as prompt optimization.

Table 1. Four-dimensional Connotation of English Writing Competence Development Path

Dimension	Core Connotation	GAI-assisted Development Performance
Cognitive Process	Writing conception, logical construction, content expression	Improve writing logic, enrich content connotation, reduce Chinglish expression
Strategy Use	Outline construction, error correction, resource supplementation, revision optimization	Master targeted GAI application strategies for different writing stages
Metacognitive Regulation	Process monitoring, effect evaluation, reflective summary	Form the habit of reflecting on writing and GAI application effect
Human-machine Interaction Mechanism	Interaction mode, prompt optimization, feedback discrimination	Establish scientific human-machine interaction mode, master prompt optimization skills

1.2 Literature Review Based on Technical Development Logic

The integration of artificial intelligence and English writing teaching has experienced three developmental stages of tool-based assistance → intelligent feedback system → GAI-based human-machine collaboration, with the role of technology changing from "passive tool" to "active collaborator", and the teaching mode changing from "teacher-centered" to "student-centered, human-machine synergy".

Tool-based assistance stage (2000s-2010s). The main application of artificial intelligence in English writing is limited to passive tool assistance such as spell check (e.g., Word spell check) and online dictionary. These tools only focus on surface-level language error correction, without involving the deep-level writing cognitive process, and cannot provide personalized feedback and strategic guidance (Evmenova & Regan, 2019). The core problem of traditional writing teaching—delayed feedback and limited resources—remains unsolved.

Intelligent feedback system stage (2010s-2020s). With the development of natural language processing technology, intelligent writing feedback systems represented by Grammarly and Turnitin emerged. These systems can conduct multi-dimensional error correction of grammar, vocabulary and sentence structure, and provide plagiarism detection and basic revision suggestions (Ranalli & Yamashita, 2022). However, such systems still have limitations such as single feedback dimension, lack of logical construction guidance and inability to generate personalized writing resources, and the interaction between humans and machines is still in a "one-way response" mode.

GAI-based human-machine collaboration stage (2022-present). The release and iteration of ChatGPT and other GAI tools have pushed the integration of artificial intelligence and English writing teaching into a

new stage of human-machine collaboration. GAI has the capabilities of text generation, semantic understanding and interactive feedback, and can provide full-process assistance for English writing from pre-writing outline construction to while-writing revision optimization and post-writing reflective summary (Chen & Lyu, 2024; Shen & Zhu, 2023). It can not only optimize language input and output, but also stimulate students' creative thinking and improve writing efficiency. However, the academic community has also raised widespread concerns about the risks of this stage, such as academic misconduct, technical dependence and factual errors in generated content (Cotton et al., 2024; Mohamed, 2023).

Existing studies have confirmed the application value of GAI in English writing, but there are still three deficiencies: (1) The theoretical framework is not clear, and the relationship between human-machine collaboration, second language acquisition and writing cognitive process is not fully clarified; (2) The connotation of English writing competence development path is broad, lacking a structured definition and dimensional division; (3) The discussion of GAI's limitations is insufficient, and the critical reflection on ethical risks and teaching backlash is not in balance with the analysis of advantages. Based on this, this study takes the above deficiencies as the research starting point, conducts empirical research on college students' GAI application status in English writing, constructs a scientific and feasible writing competence enhancement strategy system, and provides theoretical references and practical paths for the digital reform of college English writing teaching.

1.3 Research Questions and Significance

1.3.1 Research Questions

a. What is the current status of college students' use of GAI in English writing (tool preference, application scenario, usage strategy, perceived effect)?

b. What are the dual challenges faced by college students in using GAI to develop English writing competence (GAI's inherent limitations and students' intrinsic writing deficiencies)?

c. How to construct a structured English writing competence enhancement strategy system based on the three stages of writing cognitive process under the human-machine collaboration perspective?

1.3.2 Research Significance

Construct a tri-dimensional theoretical framework of GAI-assisted English writing competence development, clarify the four-dimensional connotation of the development path, and enrich the research on the integration of GAI and foreign language education; strengthen the theoretical integration of human-machine collaboration, second language acquisition and writing cognitive process, and improve the theoretical contribution of relevant research.

Based on empirical research and exploratory application cases, construct a three-stage GAI-assisted English writing competence enhancement strategy system, which provides specific and operable guidance for college students to rationally use GAI to improve writing competence; provide practical reference for college English teachers to design human-machine collaborative writing teaching activities, and promote the deep integration of GAI and English writing teaching.

2. Research Methods

2.1 Research Design

This study adopts a mixed research method combining quantitative and qualitative research, with questionnaire survey as the main method and semi-structured interview and exploratory classroom application as supplementary methods. The questionnaire survey is used to investigate the overall status of college students' use of GAI in English writing; the semi-structured interview is used to deeply explore the underlying reasons behind the questionnaire data and the specific problems faced by students; the exploratory classroom application is used to verify the feasibility of the GAI-assisted writing competence enhancement strategy and supplement the empirical basis of the study.

2.1 Questionnaire Design and Implementation

2.2.1 Questionnaire Compilation

Based on the tri-dimensional theoretical framework and four-dimensional connotation of the development path, this study developed the Questionnaire on the Current Status of College Students' Use of Generative AI in English Writing through four stages: dimension construction and initial item formulation → expert review and item optimization → pilot survey and questionnaire revision → formal survey implementation, to ensure the scientificity, validity and pertinence of the questionnaire. The questionnaire includes five core dimensions: (1) Preference for Commonly Used GAI Tools; (2) Distribution of GAI Application Scenarios; (3) Selection of GAI Usage Strategies; (4) Perceived Effects of GAI Application; (5) Problems and Coping Strategies in GAI Use. The final formal questionnaire consists of 16 items, including 8 single-choice questions, 4 multiple-choice questions and 4 5-point Likert-scale questions.

2.2.2 Questionnaire Implementation

The survey was conducted from late August to mid-September 2024 using convenience sampling. Questionnaires were distributed to college students from 12 universities nationwide (covering comprehensive, science and engineering, and liberal arts institutions) through online channels such as WeChat groups, Moments, and university forums. A total of 202 questionnaires were collected, and 200 valid questionnaires were obtained after strict screening (excluding those with excessively short response time [<3 minutes], contradictory answers, or incomplete responses), with an effective recovery rate of 99.01%. The demographic characteristics of the sample are shown in Table 2.

Table 2. Demographic Characteristics of the Sample (N=200)

Characteristic	Category	Frequency (n)	Percentage (%)
Gender	Male	67	33.5
	Female	133	66.5
Education Level	Undergraduate	140	70.0
	Postgraduate	60	30.0
CET-4 Essay Score	0-6(Low)	23	11.5
	7-12(Medium)	157	78.5
	13-15(High)	20	10.0

2.3 Semi-structured Interview

To triangulate quantitative results and explore the underlying reasons behind the questionnaire data, 6 college students were randomly selected from the 200 valid respondents (covering different genders, education levels, and CET-4 essay score ranges) for one-on-one semi-structured interviews. The interview guide included three core modules: (1) Specific experiences of GAI use in English writing; (2) Prominent problems encountered; (3) Improvement suggestions for GAI tool optimization and human-machine collaborative writing teaching. Each interview lasted approximately 30 minutes, and all interviews were audio-recorded with participants' informed consent. Interview recordings were transcribed verbatim into textual data (about 12,000 Chinese characters) for thematic analysis.

2.4 Exploratory Classroom Application

To supplement the empirical basis of the study, this study conducted a 4-week exploratory GAI-assisted English writing teaching application in a college English writing course of a comprehensive university in eastern China, with 30 sophomore undergraduates as the research objects. The teaching application is based

on the three-stage writing cognitive process, and adopts the strategy of "student autonomy first, GAI supplementary empowerment". The implementation process, teaching scenario and evaluation method are detailed in Section 5.3, and the application effect is used to verify the feasibility of the proposed enhancement strategy.

2.5 Data Analysis

SPSS 26.0 statistical software was used for descriptive statistical analysis (frequency, percentage, mean, standard deviation) of the questionnaire data, with the significance level set at $p < 0.05$. The interview data and exploratory classroom application data were coded and analyzed using thematic analysis method, and the core themes were extracted to supplement and explain the quantitative results.

3. Current Status of College Students' Use of GAI in English Writing

3.1 Preferences for Commonly Used GAI Tools and Usage Satisfaction

As shown in Table 3, ChatGPT ranked first in both usage rate and satisfaction among GAI tools for intelligent writing assistance: 75.0% of college students reported frequently using ChatGPT, and over 75.0% of users rated it as "useful" or "very useful", mainly recognizing the authenticity of its generated content, timeliness of interactive feedback, and comprehensiveness of functions. ERNIE Bot followed with a usage rate of 61.0% and a satisfaction rate of 55.0%, with advantages in the accuracy of understanding Chinese prompts and adaptability to localized content. Kimi had a usage rate of 35.5% and a satisfaction rate of 35.5%, favored by some students for its long-text processing capability. Other GAI tools (iFlytek Spark, ChatGLM, Zhipu Qingyan, etc.) had low usage rates and satisfaction rates, mainly due to insufficient targeted functions for English writing scenarios and poor stability of generated content quality.

Table 3. Usage Rate and Satisfaction of Commonly Used GAI Tools (N=200)

GAI Tool	Usage Rate (%)	Satisfaction Rate (%)	Key User Evaluations
ChatGPT	75.0	>75.0	Authentic content, timely feedback, comprehensive functions
ERNIE Bot	61.0	55.0	Accurate understanding of Chinese prompts, localized adaptability
Kimi	35.5	35.5	Strong long-text processing capability
iFlytek Spark	30.0	20.5	Need for improvement in logic and linguistic accuracy
ChatGLM	21.5	21.0	Average overall performance
Others	<20.0	<20.0	Insufficient targeted functions, unstable quality

3.2 Distribution of GAI Application Scenarios and Usage Frequency

Table 4 presents the distribution of GAI application scenarios and usage frequency in the four-dimensional development path. Framework construction before writing was the most common scenario (≥66.0%), which is highly correlated with college students' common pain point of "lack of structured thinking" in the cognitive process dimension. This was followed by grammar and sentence structure checking (58.5%) and vocabulary and expression expansion (56.0%), reflecting students' strong demand for GAI's language error correction and resource supplement functions in the strategy use dimension. The proportions of students using GAI for drafting essays (46.0%), brainstorming (40.0%), acquiring topic-related information (34.5%), and post-writing evaluation (21.5%) decreased in turn, indicating that GAI is applied throughout the writing cognitive process but with core functions concentrated in pre-writing preparation and mid-writing language optimization.

Regarding usage frequency, 55.0% of students used GAI 1–2 times per writing task, 30.5% used it 3–4 times, and only 14.5% used it 5 times or more. This suggests that most students regard GAI as an auxiliary tool rather than a replacement in the human-machine interaction mechanism dimension, with relatively rational usage behavior and no excessive dependence on GAI in the short term.

Table 4. Distribution of GAI Application Scenarios and Usage Frequency (N=200)

Category	Specific item	Proportion (%)
Application Scenarios	Framework construction before writing	≥66.0
	Grammar and sentence structure checking	58.5
	Vocabulary and expression expansion	56.0
	Drafting essays	46.0
	Brainstorming for inspiration	40.0
	Acquiring information on writing topics	34.5
	Post-writing evaluation	21.5
Usage Frequency	1-2 times per task	55.0
	3-4 times per task	30.5
	5 times or more per task	14.5

3.3 Selection of GAI Usage Strategies

As indicated in Table 5, college students showed obvious tendencies in GAI usage strategies in the strategy use dimension: 74.0% preferred to use GAI to obtain writing outline ideas, and 65.0% sought targeted feedback by providing short prompts—both reflecting "tool-empowered thinking" and conforming to the human-machine collaboration principle of "supplementary empowerment". 45.0% used GAI to generate model essays for reference, and 39.5% reviewed interaction records for writing reflection (metacognitive regulation dimension), focusing on the secondary utilization of GAI-generated content. In contrast, only 28.0% adopted the strategy of "comparing self-written versions with GAI-generated versions", reflecting a lack of critical comparison awareness in the metacognitive regulation dimension among some students. Additionally, 41.0% combined GAI with other learning tools (e.g., DeepL Write, essay grading platforms), forming a "GAI + specialized tools" mode to make up for the limitations of a single tool.

Table 5. Distribution of GAI Usage Strategies (N=200)

GAI Usage Strategy	Proportion (%)
Obtaining writing outline ideas	74.0
Providing short prompts to seek feedback	65.0
Combining with other learning tools	41.0
Generating model essays for reference	45.0
Reviewing interaction records for reflection	39.5
Comparing self-written vs. GAI-generated versions	28.0

3.4 Perceived Effects of GAI Application

Table 6 shows that college students generally held positive evaluations of GAI-assisted English writing competence development, and the perceived effects were mainly concentrated in the cognitive process and strategy use dimensions: 68.5% reported significant improvement in essay logical structure (cognitive process), 57.0% in vocabulary reserve and application (strategy use), and 52.5% in writing speed (human-machine interaction). These results verify GAI's core value in cultivating structured thinking, supplying language resources and improving writing efficiency. Additionally, 45.0% reported improved grammatical accuracy (strategy use), 36.5% stimulated creative thinking (cognitive process), and 26.5% enhanced brainstorming ability (cognitive process), indicating that GAI can play a limited role in cultivating higher-order thinking skills in the cognitive process dimension. Notably, 92.0% of students expressed willingness to continue using GAI for intelligent writing assistance, further confirming its practical value and acceptance in college English writing teaching.

Table 6. Perceived Effects of GAI Application (N=200)

Perceived Effect Dimension	Proportion of Improvement (%)
Logical structure of essays	68.5
Vocabulary reserve and application	57.0
Writing speed	52.5
Grammatical accuracy	45.0
Creative thinking	36.5
Brainstorming ability	26.5
Willingness to continue use	92.0

3.5 Problems and Coping Strategies in GAI Use

The problems faced by college students in GAI use mainly focus on two aspects: GAI's inherent limitations (tool side) and students' intrinsic writing deficiencies (user side), which run through the four dimensions of the development path and have not shown significant differentiation due to differences in students' linguistic proficiency (Table 7). In terms of GAI's inherent limitations, 70.0% reported unstable quality of GAI-generated content (e.g., irrelevant content, logical contradictions)—the most prominent problem. 49.0% noted that generated content did not meet specific writing requirements, 48.0% pointed out a lack of innovation (templated tendencies), 47.0% worried about technical dependence (human-machine interaction dimension), and 46.0% concerned about academic integrity risks (ethical dimension). In terms of students' intrinsic writing deficiencies, 78.0% admitted to simplistic expression and monotonous sentences (cognitive process), 68.5%

to insufficient vocabulary reserve (strategy use), 45.5% to slow writing speed (human-machine interaction), 43.5% to lack of pre-writing planning (metacognitive regulation), and 38.0% to repeated writing errors (strategy use).

For these problems, students adopted diverse coping strategies: over 50.0% chose to "innovate by integrating GAI feedback with personal style" (cognitive process) and "adjust prompts multiple times" (human-machine interaction), reflecting active optimization awareness in the cognitive and interactive dimensions. 49.5% critically accepted GAI's ideas (metacognitive regulation), and 47.0% insisted on independent thinking before using GAI (human-machine interaction)—indicating certain critical thinking and independent learning awareness. In contrast, only 18.0% inquired about vague feedback, and 15.5% proactively learned GAI usage skills (e.g., prompt optimization), suggesting insufficient awareness of tapping tool potential in the human-machine interaction dimension.

Table 7. Problems and Coping Strategies in GAI Use (N=200)

Category	Specific Item	Proportion (%)
Tool-related Problems	Unstable quality of generated content	70.0
	Content inconsistent with writing requirements	49.0
	Lack of innovation in generated content	48.0
	Increased dependence on GAI	47.0
	Academic integrity risks	46.0
	Difficulty understanding GAI's suggestions	21.5
	Lack of mastery skills	16.0
Personal Ability Shortcomings	Simplistic expressions & monotonous sentences	78.0
	Insufficient vocabulary reserve	68.5
	Slow writing speed	45.5
	Lack of pre-writing planning	43.5
	Repeated writing errors	38.0
Coping Strategies	Innovate with GAI feedback + personal style	>50
	Adjust prompts multiple times	>50
	Critically accept GAI's ideas	49.5
	Independent thinking before using GAI	47.0
	Clarify vague feedback by inquiring GAI	18.0
	Proactively item GAI usage skills	15.5

4. Dual Challenges of GAI-assisted English Writing Competence Development

Based on the results of the questionnaire survey, semi-structured interview and thematic analysis, the dual challenges faced by college students in using GAI to develop English writing competence are summarized as GAI's inherent limitations and application risks (tool side) and college students' intrinsic deficiencies in

English writing competence (user side). These two aspects are intertwined, jointly restricting the full play of GAI's auxiliary value in the four-dimensional development path and the essential improvement of students' writing competence.

4.1 GAI's Inherent Limitations and Application Risks

Relying on powerful natural language processing and interactive feedback capabilities, GAI has become an important tool for intelligent writing assistance in English writing teaching, but constrained by technical principles, training data and algorithmic logic, it still has many inherent limitations and application risks, including insufficient content credibility, academic integrity crisis, intensified technical dependence and ethical dilemmas. These risks are not only related to the performance of GAI itself, but also may have a negative impact on the cultivation of students' higher-order thinking abilities and the healthy development of college English writing teaching.

4.1.1 Insufficient Content Credibility: Factual Deviations and Knowledge Obsolescence

A core limitation of GAI-generated content lies in the lack of absolute guarantee for information credibility, mainly manifested in factual errors and lagging knowledge iteration. In terms of factual accuracy, GAI may generate content with fabrications, misleading information or logical contradictions even though the text is fluent and detailed (Naidoo & Max, 2023). The interview results show that some students found that the real cases, proverbs, allusions or data generated by GAI for English writing were inconsistent with reality, and some materials with claimed authoritative sources could not be verified. Direct citation of such content may impair the scientificity of writing and mislead students' cognitive process of writing content construction. In terms of knowledge timeliness, GAI's knowledge base has a significant update delay (e.g., ChatGPT's knowledge base cutoff date is July 2025), which makes it unable to access the latest research results, social hot topics or language usage trends. This limitation makes it difficult for GAI to provide effective support for writing tasks that require cutting-edge data support or dynamic background information (such as academic literature reviews and current affairs commentaries), and even may transmit outdated information, affecting the timeliness and accuracy of students' writing content in the cognitive process dimension.

4.1.2 Academic Integrity Crisis: Plagiarism and Lack of Originality

The convenience of GAI's intelligent writing assistance has brought potential risks of academic misconduct, triggering widespread controversy about academic ethics, plagiarism and assignment cheating (Straume & Anson, 2022). Traditional English writing emphasizes the complete cognitive process of "conception-drafting-revision-polishing", but GAI enables some students to quickly obtain complete essay texts or core viewpoints by inputting simple prompts, and then directly submit assignments through copy-pasting, completely bypassing key links such as brainstorming, idea organization and language refinement. The interview data shows that some students admitted to "directly applying GAI-generated viewpoints and expressions" and "taking GAI-generated content as the final draft" when completing daily English assignments, which is essentially a lack of academic integrity. More notably, some students have a vague understanding of the boundary between "reasonable reference" and "plagiarism/cheating", believing that "revision based on GAI constitutes originality". This cognitive bias further exacerbates the risk of academic misconduct and is not conducive to the cultivation of students' independent writing ability and original thinking in the cognitive process dimension.

4.1.3 Intensified Technical Dependence: Weakening of Independent Learning and Higher-order Thinking

With the popularization of GAI in English writing teaching, technical dependence has become an undeniable problem in the human-machine interaction dimension (Baidoo-Anu & Ansah, 2023). The real-time and one-stop intelligent writing assistance provided by GAI has led some students to gradually lose the willingness and ability to solve writing problems independently. During interviews, some students stated that "when encountering problems such as insufficient vocabulary, monotonous sentence structures or logical confusion in English writing, their first reaction is to turn to GAI rather than independently consulting dictionaries, studying model essays or engaging in in-depth thinking". Excessive reliance on GAI deprives students of the process of accumulating writing experience through independent exploration and trial-and-error correction, leading to a gradual weakening of their intrinsic motivation for knowledge exploration and a significant increase in learning laziness. More seriously, students are more inclined to passively accept GAI-generated content rather than actively exploring the essence of problems and putting forward personalized viewpoints, which will cause the gradual loss of critical thinking and innovative abilities, and seriously hinder the development of higher-order thinking abilities such as analysis, evaluation and creation in the cognitive process dimension—running counter to the core goal of English writing competence cultivation.

4.1.4 Ethical Dilemmas: Privacy Leakage and Algorithm Bias

In addition to the above risks, GAI's application in English writing also faces ethical dilemmas such as privacy leakage and algorithm bias. On the one hand, when students input their writing drafts, personal viewpoints and learning habits into GAI for intelligent writing assistance, their personal learning data may be collected and used without authorization, leading to the risk of privacy leakage. This not only violates students' right to information privacy, but also may affect their willingness to use GAI for deep interaction in the human-machine interaction dimension. On the other hand, GAI's training data is derived from human language text, which inevitably contains the subjective biases and value tendencies of human society (e.g., cultural bias, gender bias). These biases will be reflected in the generated content, which may mislead students' cognitive judgment and cultural cognition in the cognitive process dimension, and is not conducive to the cultivation of their cross-cultural communication competence—an important component of English writing competence.

4.2 College Students' Intrinsic Deficiencies in English Writing Competence

The application effect of GAI in intelligent writing assistance depends not only on the performance of the tool itself, but also on the users' own writing competence. Survey data shows that even with GAI assistance, college students still have significant deficiencies in the four-dimensional development path of English writing competence, including weak ability to construct writing frameworks, insufficient access to effective feedback and interference from negative mother tongue transfer. These deficiencies not only limit students' effective use of GAI in the strategy use and human-machine interaction dimensions but also may be exacerbated by the intervention of GAI in the absence of scientific guidance.

4.2.1 Weak Ability to Construct Writing Frameworks: Lack of Structured Thinking (Cognitive Process Dimension)

The core of English writing competence in the cognitive process dimension is to construct a logically clear and hierarchically distinct writing framework, which is precisely a prominent deficiency of current college students. The survey shows that 66.5% of students use GAI to assist in constructing pre-writing frameworks, which not only reflects their demand for structured writing in the cognitive process, but also indirectly confirms their insufficient ability to construct frameworks independently. In writing practice, many students

lack a sense of systematic pre-writing planning in the metacognitive regulation dimension—they have not formed a scientific cognitive process of "analyzing the topic-brainstorming-organizing logic-outlining" and have not mastered the framework characteristics of different types of essays. Instead, they often directly enter the sentence drafting stage, leading to loose text logic, poor paragraph coherence and unclear theme expression. In addition, some students blindly rely on reciting ready-made writing templates and mechanically apply them to various writing tasks, which essentially does not help them understand the internal logic of framework construction, nor can it cultivate their ability to flexibly adjust the structure according to topic requirements. This template-based writing will gradually erode students' willingness to think independently and their sense of innovation in the cognitive process dimension, resulting in a continuous decline in their learning interest and motivation.

4.2.2 Insufficient Access to Effective Feedback: Dual Constraints of Weak Language Foundation and Inefficient Feedback Utilization (Strategy Use & Metacognitive Regulation Dimensions)

The difficulty in improving English writing competence is closely related to students' lack of timely and effective feedback in the strategy use and metacognitive regulation dimensions, which stems from the dual constraints of weak language foundation and inefficient feedback utilization. In terms of language foundation, 78.0% of students have the problem of "simplistic expression and monotonous sentences", and 68.5% face "insufficient vocabulary reserve" in the strategy use dimension. These basic deficiencies make them frequently encounter difficulties in content generation and stiff language expression during writing, and even unable to produce complete and fluent texts (Chung et al., 2020). At the same time, due to the lack of self-checking awareness and ability in the metacognitive regulation dimension, many students fail to promptly identify grammatical errors, vocabulary misuse and other problems after completing writing, leading to repeated errors. In terms of feedback utilization, when facing GAI-generated feedback in the strategy use dimension, some students cannot fully understand the professional suggestions due to limited language proficiency, while others lack critical evaluation ability and blindly accept all revision suggestions, resulting in rigid writing styles and lack of individuality. Only high-quality, personalized and operable effective feedback can guide students to actively reflect on writing problems in the metacognitive regulation dimension, optimize expression strategies in the strategy use dimension, and further cultivate independent thinking and independent learning abilities.

4.2.3 Interference from Negative Mother Tongue Transfer: Language Habits and Thinking Mode Conflicts (Cognitive Process Dimension)

Chinglish is a common problem among Chinese college students in English writing, whose root cause lies in the interference of negative mother tongue transfer in the cognitive process dimension of second language acquisition. According to Lado's (1957) Contrastive Analysis Hypothesis, learners will unconsciously transfer the language rules, expression habits and thinking modes of their mother tongue to the target language, and language errors will occur when this transfer is inconsistent with the norms of the target language. There are significant differences between Chinese and English in language systems, cultural backgrounds and thinking modes: Chinese emphasizes parataxis with loose sentence structures, while English emphasizes hypotaxis with rigorous grammatical rules and logical sentence structures (Yang, 2024). These differences make college students highly susceptible to the influence of their mother tongue in English writing, resulting in typical Chinglish expressions (e.g., "Our school has many students"). In addition, Chinese thinking emphasizes "indirection and implicitness", while English writing focuses more on "straightforwardness and clear logic". This difference makes the themes of some students' English essays unclear and arguments indirect in the cognitive

process dimension, making it difficult to meet the evaluation criteria of English writing. Even with GAI's intelligent writing assistance, if students do not deeply understand the cultural backgrounds and thinking modes of English-speaking countries, it is difficult to fundamentally solve the problem of negative mother tongue transfer, and the improvement of writing competence in the cognitive process dimension is only superficial.

5. GAI-assisted English Writing Competence Enhancement Strategy System Under Human-machine Collaboration

Based on the tri-dimensional theoretical framework, four-dimensional connotation of the development path and the dual challenges identified above, this study constructs a three-stage English writing competence enhancement strategy system covering pre-writing, while-writing and post-writing (Table 8), adhering to the core principle of "student autonomy first, GAI supplementary empowerment" in human-machine collaboration. The system clarifies the respective roles and behavioral requirements of students, GAI and teachers in each stage, and integrates the four-dimensional development path of writing competence into the whole process of writing cognitive process. Meanwhile, this study verifies the feasibility of the strategy system through a 4-week exploratory classroom application, and supplements the implementation process, specific teaching scenario and multi-dimensional evaluation method to strengthen the empirical basis of the strategy.

5.1 Core Principle and Design Logic

The core principle of the strategy system is "student autonomy first, GAI supplementary empowerment, teacher scientific guidance", which clarifies the hierarchical relationship of the three subjects in human-machine collaboration: students are the main body of writing competence development, responsible for independent writing and active reflection in the four-dimensional development path; GAI is the auxiliary tool for intelligent writing assistance, playing the role of supplementary inspiration, targeted feedback and resource support in the strategy use and human-machine interaction dimensions; teachers are the scientific guide and value leader, responsible for guiding students to rationally use GAI, discerning the validity of GAI-generated feedback, and establishing a scientific human-machine interaction mechanism.

The design logic of the strategy system is based on the writing cognitive process theory (planning-drafting-revising-reflecting), and integrates the tri-dimensional theoretical framework of human-machine collaboration, second language acquisition and writing cognitive process. Each stage of the strategy is closely combined with the four-dimensional connotation of the development path, with the goal of improving students' writing competence in the cognitive process dimension, optimizing their strategy use ability, strengthening their metacognitive regulation ability and forming a scientific human-machine interaction mechanism—ultimately achieving the organic integration of "technology empowerment" and "competence-based education".

5.2 Three-stage Enhancement Strategy System

5.2.1 Pre-writing: "Independent Conception-GAI Assistance-Critical Integration" (Cognitive Process & Human-machine Interaction Dimensions)

The core goal of the pre-writing stage is to help students clarify writing directions, build logical frameworks and accumulate thematic resources in the cognitive process dimension, while avoiding over-reliance on GAI and fostering independent planning and critical thinking abilities in the human-machine interaction dimension. GAI plays the dual role of "virtual mentor" and "framework evaluator" for intelligent writing assistance: as a virtual mentor, it provides theme expansion, idea inspiration and resource support based on students'

initial thoughts; as a framework evaluator, it assists students in optimizing writing outlines to enhance the scientificity and completeness of pre-writing planning.

Students' behavioral requirements: (1) Independently complete brainstorming and preliminary drafting of writing outlines based on the writing topic, fully activating existing knowledge schemas and thinking abilities in the cognitive process dimension to form personalized writing ideas; (2) Submit self-drafted outlines to GAI to seek supplementary suggestions, expanded perspectives or relevant resource support, and selectively adopt reasonable components generated by GAI based on writing needs and thematic characteristics; (3) Request GAI to independently generate a writing outline, and through comparative analysis with the self-drafted outline, identify differences in logical structure, content dimensions and expression perspectives, explore learnable highlights, and further improve the outline (metacognitive regulation dimension).

Teachers' guiding measures: (1) Guide students to value the significance of independent conception through thematic guidance and case analysis, fostering good habits of patient thinking and systematic planning in the metacognitive regulation dimension; (2) Formulate a Pre-writing GAI Application Guide for intelligent writing assistance, clarifying outline evaluation criteria for different learning stages and converting them into standardized prompts for GAI to ensure the pertinence and adaptability of GAI's feedback; (3) Cultivate students' critical thinking, guide them to verify the authenticity, logical validity and contextual adaptability of GAI-provided information, and avoid uncritical acceptance (cognitive process dimension); (4) Instruct students to master basic prompt optimization skills (e.g., clarifying theme boundaries, defining outline structures), improving the efficiency and quality of human-machine interaction (human-machine interaction dimension).

5.2.2 While-writing: "Independent Creation-GAI Precise Feedback-In-depth Interactive Optimization" (Strategy Use & Cognitive Process Dimensions)

The core task of the while-writing stage is to assist students in completing text generation and preliminary revision in the cognitive process dimension, focusing on improving the accuracy of language expression, completeness of content and creativity of thinking, while strengthening independent writing abilities in the strategy use dimension and efficient GAI utilization skills in the human-machine interaction dimension. This stage strictly adheres to the principle of "independent creation first", and GAI acts as a "multifunctional language assistant" for intelligent writing assistance, providing targeted and multi-dimensional feedback for writing revision.

Students' behavioral requirements: (1) Complete the first draft independently based on the pre-writing outline without relying on GAI, actively mobilizing linguistic knowledge reserves and applying logical thinking abilities to solve practical writing problems such as vocabulary selection and sentence structure organization (strategy use & cognitive process dimensions); (2) Use GAI for precise revision and optimization after completing the first draft, and obtain targeted feedback on grammar error correction, vocabulary optimization, logical improvement and content expansion; (3) Conduct dialectical analysis of GAI's revision suggestions in the metacognitive regulation dimension, independently deciding to adopt, adjust or reject them based on writing intentions and textual context to avoid rigid expression caused by passive acceptance; (4) Take the initiative to seek further clarification from GAI by supplementing prompts if the suggestions are ambiguous or inconsistent with the theme, conducting in-depth human-machine interaction (human-machine interaction dimension).

Teachers' guiding measures: (1) Help students master methods to identify the effectiveness of GAI's feedback through thematic teaching (e.g., verifying grammatical rules, validating factual data), cultivating

their language discrimination abilities in the strategy use dimension; (2) Input standardized language evaluation rules into GAI to ensure the professionalism and consistency of GAI's feedback for intelligent writing assistance; (3) Encourage students to actively expose their writing shortcomings during interaction with GAI, and request GAI to provide targeted improvement plans (e.g., recommending authentic expression examples, designing personalized sentence structure training tasks); (4) Guide students to carry out human-machine collaborative innovation in the cognitive process dimension, providing GAI with personal writing styles and core viewpoints to guide it in generating diverse expression ideas, and then conducting secondary creation combined with personal thinking to form personalized and original expressions.

5.2.3 Post-writing: "Revision Report-Reflection and Internalization-Teacher-GAI Collaborative Evaluation" (Metacognitive Regulation & Four-dimensional Integration)

The post-writing stage is a key link for the internalization and transfer of writing competence, and the core goal is to help students summarize experience, identify shortcomings and consolidate improvements in the metacognitive regulation dimension, constructing a closed-loop learning model of "practice-feedback-reflection-improvement" integrating the four-dimensional development path. This stage integrates the tripartite forces of students' independent reflection, GAI-assisted review and teachers' professional evaluation, forming a synergistic empowerment effect of human-machine collaboration.

Students' behavioral requirements: (1) Write a detailed Writing Revision Report after completing the final draft revision, including GAI's application scenarios and specific feedback, comparison of core differences between the original draft and the revised version, adoption of GAI's feedback and corresponding reasons, and independent reflection on core problems and improvement directions (metacognitive regulation dimension); (2) Fully utilize the complete human-machine interaction records retained by GAI to conduct targeted review, request GAI to generate a personalized model essay integrating personal core viewpoints, writing styles and GAI's optimization suggestions, and use it as a learning reference; (3) Combine the model essay and interaction records to review the problems encountered during writing and their solutions, reflect on the effectiveness of GAI's feedback and the insufficient utilization of feedback, and accumulate experience for future writing (four-dimensional integration).

Teachers' guiding measures: (1) Establish personalized electronic learning portfolios for students based on human-machine interaction records and revision reports, comprehensively tracking students' writing processes, ability development trajectories and GAI application status to provide data support for precise teaching (four-dimensional integration); (2) Adopt a "dual-text evaluation + report commentary" model for evaluation: conduct comparative scoring of students' original drafts and final revised versions, focusing on the revision scope and progress dimensions; provide targeted comments on the revision report, affirming reasonable reflections and pointing out cognitive biases (metacognitive regulation dimension); (3) Play the irreplaceable role of professional guidance and emotional communication, formulating personalized ability improvement plans for students based on electronic portfolios, and solving students' confusion during reflection through face-to-face communication and group discussions; (4) Leverage GAI's batch processing capabilities to generate special training resources for common problems of the class (e.g., high-frequency grammatical errors, monotonous sentence structures), realizing the organic combination of "personalized guidance" and "large-scale improvement" (strategy use dimension).

Table 8. Strategies for Enhancing College Students' English Writing Ability Based on Generative Artificial Intelligence

	Pre-writing	While-writing	Post-writing
Students	1. Independently conceive writing outlines 2. Critically analyze AI feedback 3. Compare self-drafted and AI-generated outlines	1. Independently write first drafts 2. Critically analyze AI feedback 3. Revise first drafts	1. Submit revision reports 2. Compare self-revised work with AI-generated models 3. Reflect on the writing process
Generative AI	1. Provide supplementary inspiration 2. Generate writing outlines 3. Guide thinking processes	1. Provide specific feedback 2. Clarify ambiguous feedback 3. Assist in revising drafts	1. Provide interaction records 2. Generate personalized model essays 3. Support reflective writing
Teachers	1. Guide students' thinking 2. Provide AI application guidelines 3. Provide outline evaluation criteria	1. Guide students to discern AI feedback 2. Provide writing rules for AI integration 3. Facilitate feedback interpretation	1. Grade essays (original and revised) 2. Comment on revision reports 3. Establish electronic portfolios

5.3 Exploratory Classroom Application and Effect Verification

5.3.1 Implementation Process and Teaching Scenario

This study conducted a 4-week exploratory classroom application of the three-stage enhancement strategy in a college English writing course of a comprehensive university in eastern China, with 30 sophomore undergraduates (CET-4 essay score 7-12, medium linguistic proficiency) as the research objects. The teaching scenario is argumentative essay writing (a common type of college English writing), and the implementation process is based on the weekly teaching cycle, covering the whole process of pre-writing (1 week), while-writing (2 weeks) and post-writing (1 week):

Pre-writing stage (Week 1). The teacher assigned the argumentative essay topic "The Impact of GAI on College Students' Learning", and guided students to independently draft writing outlines based on the Pre-writing GAI Application Guide. Students then used ChatGPT for supplementary inspiration by inputting standardized prompts (e.g., "Please provide 3 expanded perspectives for my argumentative essay outline on

the impact of GAI on college students' learning, and match each perspective with 1 relevant real case"), and optimized their outlines through comparative analysis.

While-writing stage (Weeks 2-3). Students completed the first draft independently in the first week, and then used ChatGPT for precise revision in the second week, focusing on grammar error correction, vocabulary optimization and logical improvement. The teacher guided students to discern the validity of GAI's feedback through classroom discussion, and students conducted in-depth human-machine interaction to clarify vague suggestions (e.g., "Please explain the reason for revising this sentence and provide 2 alternative expression methods").

Post-writing stage (Week 4). Students wrote and submitted Writing Revision Report based on their original drafts, revised versions and human-machine interaction records. The teacher established electronic learning portfolios for each student, adopted the "dual-text evaluation + report commentary" model for evaluation, and conducted one-on-one personalized guidance based on the portfolios. GAI generated personalized model essays for each student based on interaction records, and the teacher guided students to conduct comparative imitation and reflective summary in the classroom.

5.3.2 Multi-dimensional Evaluation Method and Application Effect

This study adopted a multi-dimensional evaluation method combining quantitative scoring and qualitative evaluation to verify the application effect of the strategy system: quantitative scoring includes the scoring of original drafts and revised versions (from the aspects of logical structure, vocabulary application, grammatical accuracy and content originality, full score 100); qualitative evaluation includes the analysis of students' revision reports, human-machine interaction records and classroom reflection feedback.

The application effect shows that the three-stage enhancement strategy system under the human-machine collaboration perspective has a significant positive effect on improving college students' English writing competence: (1) Quantitative results: The average score of students' revised versions (82.3) was 15.6 points higher than that of the original drafts (66.7), with the most significant improvement in logical structure (21.2 points) and vocabulary application (18.5 points), which is consistent with the questionnaire results that GAI can significantly improve students' writing logic and vocabulary application; (2) Qualitative results: 90.0% of students completed the revision report with detailed reflection and clear improvement directions (metacognitive regulation dimension), 83.3% of students mastered basic prompt optimization skills (human-machine interaction dimension), and 76.7% of students could independently discern the validity of GAI's feedback and conduct in-depth human-machine interaction (strategy use dimension). In addition, the classroom reflection feedback shows that students' independent writing awareness and critical thinking ability have been significantly improved, and there is no phenomenon of excessive dependence on GAI—verifying the effectiveness of the core principle of "student autonomy first, GAI supplementary empowerment".

6. Conclusion

This study explores the development path of college students' English writing competence under human-machine collaboration, with the integrated application of Generative Artificial Intelligence (GAI) in college English writing teaching as the research focus. Based on the tri-dimensional theoretical framework integrating human-machine collaboration, second language acquisition and writing cognitive process, the study clarifies the four-dimensional connotation of English writing competence development path (cognitive process, strategy use, metacognitive regulation, human-machine interaction mechanism). Through a mixed research

method of questionnaire survey, semi-structured interview and exploratory classroom application on 200 college students from 12 Chinese universities, it systematically analyzes the current status, dual challenges and practical strategies of GAI-assisted English writing learning.

The empirical results show that ChatGPT is the most widely used GAI tool for college students, with pre-writing framework construction as the primary application scenario; 92.0% of students are willing to continue using GAI for writing assistance, and GAI can significantly improve students' writing logical structure and vocabulary application. Meanwhile, the study identifies dual challenges in GAI-assisted English writing competence development: GAI itself has inherent limitations such as unstable generated content quality, academic integrity risks and technical dependence, while college students have prominent writing deficiencies including weak structured thinking, insufficient vocabulary reserves and severe negative mother tongue transfer, which jointly restrict the full play of GAI's educational value.

In response to these problems, this study constructs a three-stage GAI-assisted English writing competence enhancement strategy system adhering to the principle of "student autonomy first, GAI supplementary empowerment, teacher scientific guidance". The exploratory classroom application verifies the effectiveness of this system: it not only significantly improves students' writing scores (especially in logical structure and vocabulary application) but also cultivates students' critical discrimination ability of GAI feedback and scientific human-machine interaction skills, avoiding excessive technical dependence.

This study enriches the theoretical research on the integration of GAI and foreign language education by constructing a clear theoretical framework and defining the connotation of writing competence development path and provides practical strategies for college English writing teaching reform. It proves that scientific human-machine collaboration can realize the organic integration of "technology empowerment" and "competence-based education", making GAI an effective auxiliary tool for improving college students' English writing competence.

This study has certain limitations: the research sample is selected by convenience sampling, and the exploratory classroom application has a short duration. Future research can expand the sample coverage, conduct long-term tracking experiments, and construct differentiated GAI application strategies for students with different writing proficiency levels. In addition, in-depth research on the construction of academic integrity evaluation mechanisms and technical dependence prevention systems in GAI-assisted writing teaching is also needed.

In the digital education era, the deep integration of GAI and college English writing teaching is an inevitable trend. Only by taking students as the main body, with teachers' scientific guidance and rational GAI application, can we give full play to GAI's technical advantages, effectively improve college students' English writing core literacy, and cultivate compound talents with cross-cultural communication competence and innovative thinking, so as to promote the high-quality development of college English education.

DATA AVAILABILITY STATEMENT

All data generated or analyzed during this study are included in this article. The data that support the findings of this study are available from the corresponding author upon reasonable request.

AUTHOR CONTRIBUTIONS

You Ma is responsible for the overall topic selection, data collection, manuscript drafting, as well as data analysis and processing, and serves as the first author of the paper. Hui Shi is responsible for revising the manuscript and providing revision suggestions, and acts as the corresponding author.

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COMPETING INTERESTS

Hui Shi declares that she has no conflict of interest. You Ma declares that he has no conflict of interest.

AUTHOR AGREEMENT

All authors have agreed to the submission and have approved the final version of the manuscript.

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