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An Exploration of the Impact of Generative Artificial Intelligence on College Students' Higher-Order Thinking Skills: A Teaching Practice Study

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Abstract: This study aims to explore the impact of generative artificial intelligence (abbreviated as GAI) in higher education on students' learning experience, learning outcomes, and higher-order thinking skills (abbreviated as HOTS). By comparing GAI-assisted learning with traditional internet search-based learning, as well as collaborative learning with independent learning under GAI assistance, this research adopts methods such as questionnaire surveys, informal interviews, teaching observations, and work analysis to examine performance differences under different learning modes. The results show that, compared with traditional internet search learning, GAI-assisted learning can promote the development of students' critical and creative thinking abilities to a certain extent, and that collaborative learning under GAI is more effective than independent learning. The effectiveness of GAI applications is influenced by multiple interdependent factors, including:(1) technical infrastructure (hardware/software availability and network stability), (2) learner capabilities (foundational GAI operational proficiency and digital literacy), (3) pedagogical support (teacher guidance quality and feedback mechanisms), and (4) cognitive readiness levels, which collectively determine the efficacy of GAI applications in educational contexts.

1. Introduction

High-quality development is the primary task of building a modern socialist country in an all-round way. It is the key to realizing modernization under the new background of technological progress and international competition. Cultivating students' HOTS is an issue that educational researchers must confront today. It is an educational pursuit under the goal of cultivating well-rounded individuals in higher education, and a necessary concern to build an educational powerhouse and achieve high-quality development.

GAI is a new type of artificial intelligence capable of generating new content [1]. Artificial intelligence is not only a scientific issue, but also an educational and social issue. If human civilization is to continue, facing artificial intelligence proactively is the first step we must take [2]. GAI will not disappear and is unlikely to be completely banned. Its impact on education is still in the early stages.

As a university teacher, rather than worrying about students' improper use of GAI, we should consider the educational potential of GAI and adopt more cautious yet proactive methods to guide students in using it properly. As a technological tool that can revolutionize educational concepts and reshape educational forms, GAI has rapidly become an important factor in teaching innovation in universities. Research on GAI-enabled teaching practices in universities is beneficial for achieving modernization of teaching, coping with challenges brought by technological waves, and providing momentum for innovative development in intelligent-era university education. Therefore, this study attempts to explore the impact of GAI on students' learning experience, learning outcomes, and HOTS through classroom practice, aiming to help students view and use GAI rationally and appropriately to support their learning.

2. Current State of Research

2.1. Current Status of Research on the Educational Application of GAI

GAI (GAI) refers to artificial intelligence technology that automatically generates content based on prompts expressed through a system of symbolic representations used by human thinking [3]. On November 30, 2022, the AI lab OpenAI released ChatGPT (Chat Generative Pre-trained Transformer),ushering the global AI industry into a new track of GAI, which is regarded as "a milestone in the development of the AI field" [4]. It not only provides strong support for large-scale personalized learning [5] but also, through its ability to engage in multi-round continuous natural language dialogue, offers the possibility for human-machine collaboration to gradually replace the traditional classroom teaching model [6]. Subsequently, similar Chinese GAI tools such as Wenxin Yiyan, Doubao, iFlytek Spark, Tongyi Qianwen, etc., have emerged one after another, gradually changing the way humans learn and work. Since then, the impact of GAI on education has attracted considerable attention from scholars.

However, while GAI brings convenience to teaching and learning for teachers and students, it also raises numerous concerns, especially regarding students using GAI to directly complete assignments or cheat [7], which weakens students' HOTS [8]. Consequently, the New York City Department of Education [9], Italy [10], Australia's New South Wales and Queensland [11], and the University of Hong Kong in China [12], among others, issued explicit bans on the use of ChatGPT by students in schools. However, with increasing familiarity with GAI and more thorough evaluations, some regions have since lifted the bans [13].

In April 2023, UNESCO released the Quick Start Guide on ChatGPT and AI in Higher Education [14]. The University of Alberta in Canada developed reports and manual guides for frontline teachers [15]. In July 2023, China issued the Interim Measures for the Management of GAI Services [16]. In September of the same year, UNESCO again released the Guidance for GAI in Education and Research [3], comprehensively analyzing the existing risks of GAI, and conveying recommendations to education practitioners, aiming to guide the proper and standardized use of GAI so that it can better integrate into education. In 2024, China's Ministry of Education launched the "AI Empowerment for Education" initiative, aimed at promoting the integration of teaching and learning through AI, and improving national digital education literacy and skills. This marks China's entry into a new era of intelligent education. The application of GAI in the education field has become a focal point of research.

Researchers have conducted extensive and in-depth reflective studies on GAI, dialectically analyzing the applicability and transformative potential of GAI in supporting education [17] [18] [19], exploring more targeted management and application strategies, as well as innovative educational action strategies and methodological approaches [20] [21] [22] [23]. Some have constructed instructional models for the era of GAI [24], while others have validated the impact of GAI on learning outcomes through detailed instructional designs and practical implementations [25] [26] [27] (Li, Y. et al., 2024; Zheng, L. Q. et al., 2024; Coffey, 2024), and proposed practical pathways for integrating GAI into specific courses [28] and mechanisms by which GAI affects creative potential [29].

These existing studies have laid a solid foundation for this research. However, the deep application of GAI technology in education requires teachers to organically integrate these technologies into classroom instruction [30]. A review of the existing literature reveals that the educational application of GAI is still in the exploratory phase and requires broader and deeper practical investigation.

2.2. Research Status of Higher-Order Thinking Skills in the Era of GAI

Research on HOTS began early, tracing back to the 1960s, peaked in the 1980s and 1990s, and has remained relatively stable after 2000. In recent years, with the rapid development of intelligent technologies, the number of related studies has once again increased. In China, research on HOTS began in the early 21st century but did not see a significant rise in attention until 2016. In 2016, the Core Literacy System for Chinese Students' Development was released, followed by the General High School Curriculum Plan and Standards in 2017. That same year, the 19th National Congress proposed the requirement for “high-level talent cultivation and high-quality educational development.” Since 2017, domestic research on HOTS has significantly increased. The 2020 release of the Overall Plan for Deepening the Reform of Education Evaluation in the New Era led to another sharp rise in research the following year. In 2022, with the strong emergence of GAI, the number of studies began another new wave of growth starting in 2023. It is evident that research on HOTS is deeply rooted in the needs of educational reform and development. Helping learners shift their development focus to cultivating HOTS is the core of all 21st-century learning frameworks [31]. The development and cultivation of HOTS are urgent demands of our time and education.

The rapid development of artificial intelligence technology has inevitably impacted higher education, leading to a dramatic transformation in how knowledge is produced, disseminated, delivered, and stored. Traditional school education and curriculum models centered on knowledge transmission have been cornered [22]. Education must place more focus on students' HOTS such as critical thinking and creative thinking. Accordingly, the core of talent cultivation and evaluation should be HOTS in the context of digital information technologies.

In the era of GAI, changes in information, knowledge, teaching, and learning pose many challenges to the cultivation of HOTS in higher education. The connotation of HOTS is also exhibiting new forms and corresponding features. In educational practice, the main arena for cultivating HOTS is the classroom. Technology empowerment and the reshaping of the classroom learning environment create favorable conditions for the development and cultivation of HOTS. Higher education must take action to respond to this situation, serving the cultivation of HOTS and meeting the needs of social development and national goals [32].

In June 2023, to respond to the urgent call of building a strong education system in the new era, East China Normal University held a "Symposium on Building a Strong Education Nation and Cultivating Higher-Order Abilities," inviting experts and scholars to jointly discuss how to build a strong educational system based on cultivating higher-order abilities. Some researchers pointed out that the transformation of teaching in higher education in the AI era is aimed at cultivating HOTS [32]. Intelligent technology should be used to assist students in developing HOTS [33], and the elements, relationships, assessments, and cultivation strategies for HOTS in the digital age have been deeply discussed [34]. Specific paths for cultivating learners' HOTS under the empowerment of AI have also been constructed [35]. Li Haifeng and others used tools such as Wenxin Yiyan, the Feishu development platform, and learning analytics technologies to develop several intelligent chatbot systems. They constructed a human-machine debate-based inquiry teaching model [36] and a human-AI collaborative research-based teaching model [37] to support the cultivation of students' HOTS. Zhang Jing constructed a HOTS teaching model for translation, focusing on six aspects: teaching goals, teaching resources, teaching contexts, teaching activities, teaching evaluations, and teacher-student relationships. She used AIGC's technological advantages to design specific lessons illustrating the implementation of this model [31]. Through the literature review, it is found that how to cultivate HOTS in college students in the era of GAI has attracted widespread attention from scholars. However, systematic research and practical exploration remain insufficient. Existing research has laid a good foundation for this study and provided concrete references for subsequent instructional design and practice. Therefore, based on previous studies, this research attempts to apply GAI in college classroom practice to assist students' learning and explore the impact of intelligent technology-enhanced teaching on students' learning experience, learning outcomes, and HOTS.

3. Research Design on the Impact of GAI on Student Learning

3.1. Research Questions

This study aims to explore the impact of GAI on college students' learning. The specific research questions are as follows:

(1) Compared with traditional internet search-based learning support, how does using GAI to assist with learning tasks differ in terms of students' learning experience, learning outcomes, and higher-order thinking skills?

(2) Compared with using GAI to assist in collaborative task completion, how does using GAI to assist in independent task completion differ in terms of students' learning experience, learning outcomes, and higher-order thinking skills?

3.2. Research Instrument

This study uses a questionnaire survey as the primary research instrument. The questionnaire design refers to Bloom's taxonomy of cognitive learning objectives [38], which classifies learning goals from low to high levels as remembering, understanding, applying, analyzing, evaluating, and creating. Among these cognitive processes, analyzing, evaluating, and creating are categorized as higher-order thinking skills. These skills primarily address ill-structured problems and are demonstrated through learners' problem-solving competence, decision-making capacity, critical thinking, and creative thinking [39]. Within Bloom's revised taxonomy, the cognitive domains of analyzing, evaluating, and creating constitute higher-order thinking skills (HOTS). These competencies specifically target ill-structured problem spaces, manifested through measurable dimensions including (a) adaptive problem-solving strategies, (b) evidence-based decision-making frameworks, (c) critical evaluation of information validity, and (d) generative creative thinking processes (Tian, 2020).

In this study, the questionnaire's higher-order thinking dimensions include four major aspects: critical thinking, innovative thinking, problem-solving ability, and decision-making ability. At the same time, to ensure comprehensiveness, the questionnaire also includes items on students' learning experiences and learning outcomes.

3.3. Research Participants

The participants of this study are students in one class of the college-wide public course "Educational Technology and Application," taught by the researcher. The class has 113 students. Classes take place in a computer lab, where each student has access to a computer with internet connectivity. A preliminary survey showed that students have high expectations for the application of GAI in teaching. An overwhelming majority (99 out of 114) expressed willingness to try using GAI to assist with learning tasks. However, most students were unfamiliar with GAI: many had only heard of it, and a few had used it, but only to a limited extent.

3.4. Experimental Design

To explore the two research questions mentioned above, this study adopts an experimental design, divided into two stages.

3.4.1. Comparing the effectiveness of GAI-assisted learning versus internet search-assisted learning

For the first research question, students work in groups to collaboratively complete a digital instructional design. Students are randomly assigned to experimental and control groups. The experimental group uses GAI to collaboratively complete the learning task, while the control group uses internet search to assist collaboration. After completing their projects, students submit them to an online learning platform, where peer evaluation and teacher evaluation take place. After class, a questionnaire is used to investigate the impact of the different learning support tools on students' learning experience, learning outcomes, and higher-order thinking skills.

3.4.2. Comparing the effectiveness of GAI-assisted collaborative learning versus independent learning

For the second research question, students use GAI to create a PowerPoint teaching presentation based on the digital instructional design they completed earlier. Students are randomly reassigned into experimental and control groups. The experimental group uses GAI to collaborate on completing the learning task, while the control group uses GAI to complete the learning task independently. Again, after task completion, a questionnaire is used to assess the impact of the different learning modes on students' learning experience, learning outcomes, and higher-order thinking skills.

In summary, students use GAI to assist in creating teaching presentation slides based on the completed instructional design. The experimental group continues to engage in collaborative learning with GAI support, while the control group switches to independent learning with GAI support.

4. Research Practice and Data Collection

4.1. Implementation Process

This experiment spanned three class sessions. Before class, the teacher had already clarified the learning objectives and task procedures, and introduced the basic operations of GAI (Generative AI) tools using examples such as Wenxin Yiyan, Doubao, iFlytek Spark, and Tongyi Qianwen. Students had already been grouped and made the necessary preparations for completing the task smoothly. For example, they had learned the basic elements of digital instructional design, could distinguish between digital instructional design and teaching courseware, and had collaboratively selected specific content for upcoming digital teaching design based on their major and the new curriculum standards.

The practice in this study is divided into two stages, each including four parts: task assignment, execution, submission, and evaluation.

4.1.1. Completing digital instructional design using GAI or internet search assistance

Task Assignment and Execution:Students were randomly divided into experimental and control groups. The experimental group collaborated using GAI tools to complete the digital instructional design, while the control group collaborated using traditional internet searches for assistance. Students in the experimental group used GAI tools (e.g., Wenxin Yiyan, Doubao, iFlytek Spark, Tongyi Qianwen) to assist in completing the task. All students were required to complete the learning task through group collaboration in class.

Submission and Evaluation:Each group submitted their final digital instructional design document to the designated online learning platform before the end of class. After class, students conducted peer evaluations and completed a questionnaire.

4.1.2. Using GAI to collaborate or work independently to produce PPT teaching courseware

Task Assignment and Execution:Students were re-randomized into experimental and control groups. The experimental group used GAI to collaboratively complete the PPT courseware, while the control group used GAI to complete the task independently—each student in the control group submitted an individual PPT, while each group in the experimental group submitted one collaborative PPT.

Submission and Evaluation:All students submitted their PPTs to the same online learning platform before the end of class and completed a questionnaire in class. Afterward, they also participated in peer evaluations via the platform.

4.1.3. Artifact Appreciation and Feedback

After the two stages of tasks were completed, the teacher led a collective appreciation and critique session of student artifact in class. This guided students to recognize the potential advantages and common problems of using GAI in learning, emphasized technological ethics and intellectual property issues, and helped students develop a rational understanding and better use of GAI.

4.2. Data Collection

Data were collected throughout the teaching practice via questionnaires, informal interviews, teaching observations, and artifact analysis.

Questionnaire:The questionnaire was distributed online via "Questionnaire Star." Because the first round was completed voluntarily after class, 99 valid responses were collected. In the second round, the questionnaire was filled out immediately after task completion in class, resulting in 113 valid responses.

Informal Interviews:After each task, a few students were randomly selected for informal interviews to gain detailed insights into their learning experiences and views on GAI-assisted learning, supplementing the questionnaire results.

Observations:During task completion, the teacher intentionally observed students’ learning attitudes and behaviors.

Artifact Analysis:Student-submitted digital teaching designs and PPT courseware were collected and analyzed, with reference to peer reviews.

5. Research Results Analysis

5.1. Survey Results Analysis

5.1.1. Comparison of the Effectiveness Between GAI-Assisted Learning and Traditional Internet Search-Assisted Learning

The study employed an independent samples t-test to determine the impact of using GAI-assisted learning on students' learning. The results showed no significant difference between students using GAI-assisted learning and those using traditional internet search-assisted learning in terms of learning experience, learning outcomes, and higher-order thinking skills. A further comparison of the mean scores revealed that students using GAI-assisted learning for the first time generally scored lower in learning experience and learning outcomes compared to those using internet search. Regarding higher-order thinking, students using GAI scored lower in problem-solving and decision-making abilities but higher in critical and creative thinking than their counterparts using traditional internet searches. See Table 1 for details.

Table 1: Independent Samples T-Test on the Impact of GAI-Assisted Learning

Dimension	Internet Search	GAI-Assisted	Independent Samples T-Test	
	Mean	Mean	T-value	Sig. (2-tailed)
Learning Experience	4.0546	3.9712	.663	.510
Learning Outcome	4.0431	3.9878	.445	.657
Critical Thinking	3.7874	3.8944	-.817	.416
Creative Thinking	3.7701	3.8463	-.556	.580
Problem-Solving	3.9770	3.9268	.415	.679
Decision-Making	3.9310	3.7639	1.271	.208

The results indicate that although GAI tools offer convenience, their use in learning is still a novel experience. Students need time to adapt to such new technologies. Therefore, their first experience using GAI for learning did not yield ideal results in terms of learning experience and outcome. Additionally, informal interviews revealed that students' unfamiliarity with GAI operations also affected their learning experience and actual performance. Nonetheless, GAI's multi-turn question-answer capability can effectively support the development of students' critical and creative thinking through human-AI collaboration.

5.1.2. Comparison of the Effectiveness Between GAI-Assisted Collaborative Learning and Independent Learning

Table 2: Independent Samples T-Test on the Impact of GAI-Assisted Collaborative and Independent Learning

Dimension	GAI Collaborative	GAI Independent	Independent Samples T-Test	
	Mean	Mean	T-value	Sig. (2-tailed)
Learning Experience	4.1824	4.0087	1.467	.145
Learning Outcome	4.1689	4.0321	1.295	.198
Critical Thinking	3.9685	3.9223	.344	.732
Creative Thinking	4.0495	3.8628	1.545	.125
Problem-Solving	4.0811	3.9572	1.049	.297
Decision-Making	3.9955	3.9064	.723	.471

The study again used an independent samples t-test to evaluate the impact of collaborative vs.

independent learning when both are supported by GAI. The results showed that students engaged in collaborative learning with GAI scored higher in learning experience, outcomes, and higher-order thinking skills compared to those who learned independently. See Table 2 for details.

Although the differences were not statistically significant, collaborative learning proved more conducive to leveraging GAI's advantages and was more effective in developing higher-order thinking skills. Students mentioned in informal interviews that group discussions around GAI-generated content were more engaging, while those in independent learning were more likely to rely directly on GAI outputs.

Comparing Tables 1 and 2 reveals that students' scores in the second use of GAI-assisted collaborative learning were consistently higher than in their first use. This confirms the earlier finding that students' acceptance of GAI is a gradual process.

5.2. Analysis of Classroom Observation Results

5.2.1. First Classroom Observation

Through in-class walkthroughs, the instructor observed that both the experimental and control groups began by discussing and delegating tasks before starting hands-on work. In the experimental group, students followed various task completion processes. Some groups first used GAI to generate a basic digital instructional design plan, then copied it into a Word document for group discussion, revision, and formatting. Other groups conducted multi-turn conversations with GAI, discussed the first draft results, and continued to revise the content using GAI, finally copying it into Word for formatting.

Some groups compared the output of different GAI tools (e.g., Wenxin Yiyan, Doubao, iFlytek Spark, Tongyi Qianwen), selected content selectively, and edited it in Word. A few groups were unfamiliar with GAI operations, encountering issues such as not knowing how to log in or where to input prompts. Observing the learning process, the instructor noticed that some groups held a skeptical attitude toward GAI-generated content, while others showed expressions of admiration. In contrast, students in the control group remained calm, quietly discussing general steps in digital instructional design, focusing on instructional steps and activity development. Similarly, group dynamics varied within the control group—some collaborated closely throughout, while others preferred task division with individual execution.

It's worth noting that frequent hardware/software issues and network latency disrupted the learning process, with more pronounced effects in the experimental group using GAI.

5.2.2. Second Classroom Observation

Compared to the first session, students became significantly more familiar with GAI. The instructor observed that whether in group or individual learning settings, most students preferred to use GAI to auto-generate PowerPoint presentations based on their instructional designs. Some first transformed the design into an instructional outline before generating the PPT, while others created the PPT first and modified it afterward.

It's notable that students working independently submitted their work more quickly than collaborative groups. Nevertheless, ongoing technical and network issues continued to disrupt learning progress.

5.3. Analysis of Student Artifact

An analysis of student submissions from both groups showed that overall, the GAI-assisted outputs were more standardized in format compared to those produced using internet searches, but they lacked depth.

To evaluate the artifact, the instructor held an in-class critique session. During the review, students independently identified several issues. For example, while GAI-assisted projects were completed faster and looked more polished, a comparison of multiple submissions revealed that the designs followed repetitive templates and even shared common mistakes. The PPT slides generated via GAI were limited in style, highly "techno-stylized," and overly formulaic. Without post-generation critical revisions or creative adaptations, many artifacts ended up looking too similar.

6. Research Conclusions

This study conducted a systematic experimental design, teaching practice, and data analysis on the application of Generative AI (GAI) in higher education instruction and yielded the following conclusions:

6.1. GAI-Assisted Learning Enhances the Development of Higher-Order Thinking Skills

The findings clearly show that while students' initial experiences and outcomes with GAI were not ideal, their scores in critical and creative thinking were higher than those using traditional internet searches. This indicates that GAI can effectively foster higher-order thinking skills, particularly in critical and creative thinking, during the learning process.

6.2. Reliable Hardware, Software, and Network Infrastructure Are Prerequisites for GAI-Assisted Learning

During the experiment, hardware/software issues and network instability frequently disrupted the learning process, negatively affecting students' experiences and outcomes. Therefore, for GAI to support learning effectively, stable infrastructure is essential. Educational institutions must ensure their facilities can support the proper functioning of GAI tools.

6.3. Collaborative Learning Is Better Suited to GAI-Assisted Learning

Collaborative learning promotes interaction and exchange among students, allowing full use of GAI's multi-turn dialogue capabilities. Students in collaborative settings demonstrated better learning experiences and outcomes and showed greater development in higher-order thinking. Thus, incorporating GAI into collaborative instructional designs is recommended.

6.4. Mastery of Basic GAI Operations Is Key to Effective GAI-Assisted Learning

As students were initially unfamiliar with GAI, operational difficulties affected their learning experiences and outcomes and hindered the development of higher-order thinking. Before integrating GAI into instruction, educators should provide demonstrations, training, and technical support to help students quickly master GAI usage. This will enable learners to effectively filter, assess, and apply digital resources in an information-rich environment.

6.5. Teacher Guidance and Feedback Are Central to GAI-Assisted Learning

As a new instructional tool, GAI presents many uncertainties. Its successful integration depends heavily on teacher facilitation. Without proper guidance, GAI can cause issues, and its benefits in innovative teaching cannot be realized. Teachers must guide students in the rational and ethical use of GAI, helping them avoid pitfalls related to technology ethics and intellectual property while enhancing learning outcomes and cognitive development.

6.6. Students' Digital Literacy and Cognitive Ability Affect the Effectiveness of GAI-Assisted Learning

The quality of GAI output varies greatly depending on how prompts are crafted. Knowing how to ask the right questions is essential for accessing high-quality content. Furthermore, students must use their digital literacy and cognitive skills to filter, interpret, and apply GAI outputs. If students accept GAI content uncritically, it may lead to problems. Therefore, improving students' digital literacy and cognitive capacity is key to making GAI a beneficial tool in education.

As an emerging tool, GAI holds great potential in education but also presents significant challenges. Educational practice should align with technological features to create engaging environments and optimize instructional design, ultimately leveraging GAI to support students' comprehensive development.

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