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Research on the Impact of Generative AI on Undergraduate Freshmen's Learning of Public Basic Mathematics and Physics

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Abstract: *Generative AI technology has become a routine auxiliary tool for college students'mathematics and physics learning, yet its impact mechanism on first-year undergraduates' foundational STEM education remains unclear. This study examined 60 first-year students at Guangdong University of Petrochemical Technology through questionnaire surveys and mediation analysis, investigating the intrinsic relationships between AI usage frequency, learning strategies, and academic performance. Findings reveal that AI usage frequency influences learning outcomes through two competing pathways: positive learning strategies serve as a full positive mediator, while negative learning biases act as a full negative mediator. Students exhibit high-frequency AI usage patterns, demonstrate result-oriented empowerment perceptions, and commonly experience cognitive-behavioral tensions. The results indicate that generative AI serves as a "double-edged sword" in first-year STEM education, with ultimate effectiveness determined by students' learning strategies. Based on these findings, recommendations include strengthening process-oriented guidance and redefining the value of AI tools in pedagogical practices.*

Keywords: *Generative AI, Freshman Students, Public Basic Mathematics and Physics Disciplines, Mathematical Learning Strategies*

I. Introduction

1.1 Research Background and Motivation

Generative AI technologies centered on large language models are driving higher education into a critical phase of digital transformation. Dialog-based AI tools such as Deepseek, Doubao, and Qianwen, leveraging their core strengths—including real-time interaction, personalized responses, and multi-scenario adaptability—have become deeply integrated into every aspect of undergraduate learning, serving as essential auxiliary tools for students tackling academic challenges. As the cornerstone of STEM education, public foundational mathematics and physics disciplines exhibit three key characteristics: logical progression, rigorous derivations, and exercise-driven learning. These subjects not only form the foundation for building students' professional knowledge systems but also serve as vital vehicles for cultivating logical thinking and scientific literacy, making them prime application scenarios for generative AI-assisted learning among undergraduates.

For first-year undergraduate students, the study of mathematics and physics inherently occurs during a critical transitional phase marked by challenges. The shift from high school to university sees a dramatic increase in the volume of knowledge, the level of abstraction, and the complexity of derivations required in these subjects,

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while teaching methods evolve from teacher-centered instruction to self-directed learning. Most freshmen face the academic dilemma of "understanding lectures but struggling with problem-solving," and their adaptation during this stage directly determines their subsequent academic progress and professional development. The widespread adoption of generative AI offers freshmen a new approach to promptly overcome learning obstacles and lower the barrier to independent study; however, it also introduces potential risks such as induced mental inertia, heightened tool dependency, and cognitive outsourcing. Its impact on first-year students' mathematics and physics learning exhibits a distinct "double-edged sword" characteristic.

The academic community has conducted multidimensional investigations into the impact of generative AI on college students 'learning. Existing research either theoretically analyzes AI's negative effects on students 'independent thinking and intellectual autonomy or empirically validates the dual pathways through which AI enhances learning. However, a significant research gap persists: most studies remain theoretical in nature, while empirical studies primarily focus on language and humanities disciplines. For mathematics and science—fields that emphasize both process and outcome—and particularly during the critical transition period of first-year undergraduate studies, the underlying mechanisms, transmission pathways, and contextual constraints through which generative AI influences students' mathematical and scientific learning have yet to be systematically empirically elucidated. Clarifying the complex relationship between generative AI and first-year students' mathematical and scientific learning, as well as identifying the core logic and potential risks of technological empowerment, constitutes the primary motivation of this study.

1.2 Research Objective

This study focuses on first-year undergraduate students, examining their learning contexts in public foundational mathematics and physics courses. Its primary objective is to systematically elucidate how generative AI influences mathematics and physics learning among freshmen, clarifying the intrinsic relationships among AI usage frequency, learning strategies, and academic performance. The findings provide empirical evidence to support teaching reforms in foundational mathematics and physics courses at universities and guide students in the rational use of AI tools.

Under this central objective, this study first investigates the current usage patterns of generative AI among first-year undergraduate students in mathematics and physics learning, examining behavioral and cognitive characteristics such as frequency of use, core application scenarios, tool dependency levels, perceived empowerment, and risk awareness. Building on this foundation, the study evaluates the differential impacts of generative AI usage frequency on positive learning strategies versus negative learning biases, as well as their respective positive facilitative and negative inhibitory effects on academic performance in STEM subjects, thereby validating the four core hypotheses proposed in this research. Additionally, through mediation effect tests, the study clarifies the competitive mediating role of positive learning strategies and negative learning biases between AI usage frequency and learning outcomes, elucidating the primary transmission pathways through which generative AI influences first-year students' STEM performance. Finally, based on empirical findings, the study proposes optimized teaching strategies for public foundational mathematics and physics education tailored to the digital age, providing actionable guidance for shifting students from "answer acquisition" to "process reflection" and transforming AI from a "problem-solving tool" into a "thinking companion."

1.3 Research Significance

This study investigates the mechanisms by which generative AI influences mathematics and science learning among first-year undergraduate students, holding significant theoretical value and practical implications. Theoretically, this research fills a gap in empirical studies examining the impact of generative AI on learning within mathematical and scientific disciplines. By analyzing the core characteristics of these subjects, it enriches research findings in the integration of generative AI with higher education. Additionally, the study expands the application scenarios of the competitive mediation effect model in educational research, clarifies the dual reverse pathways through which AI affects learning outcomes, confirms the full mediating role of learning strategies, and deepens the theoretical understanding of how AI empowers student learning. It also provides new perspectives and empirical evidence for studying learning behaviors during the academic transition period for freshmen. Practically, the conclusions offer actionable guidance for reforming teaching methodologies in foundational mathematics and science courses at universities, helping institutions align with talent development requirements in the digital age while optimizing course design and assessment systems. For educators, the findings provide precise instructional strategies to identify high-risk student groups, implement targeted tiered interventions, and design AI-integrated reflective learning tasks. For freshmen, the study serves as a reference for refining AI usage practices—helping them recognize the "double-edged sword" nature of AI, correct negative usage patterns, adopt effective learning strategies, and achieve dual improvements in core mathematical/scientific competencies and self-directed learning abilities.

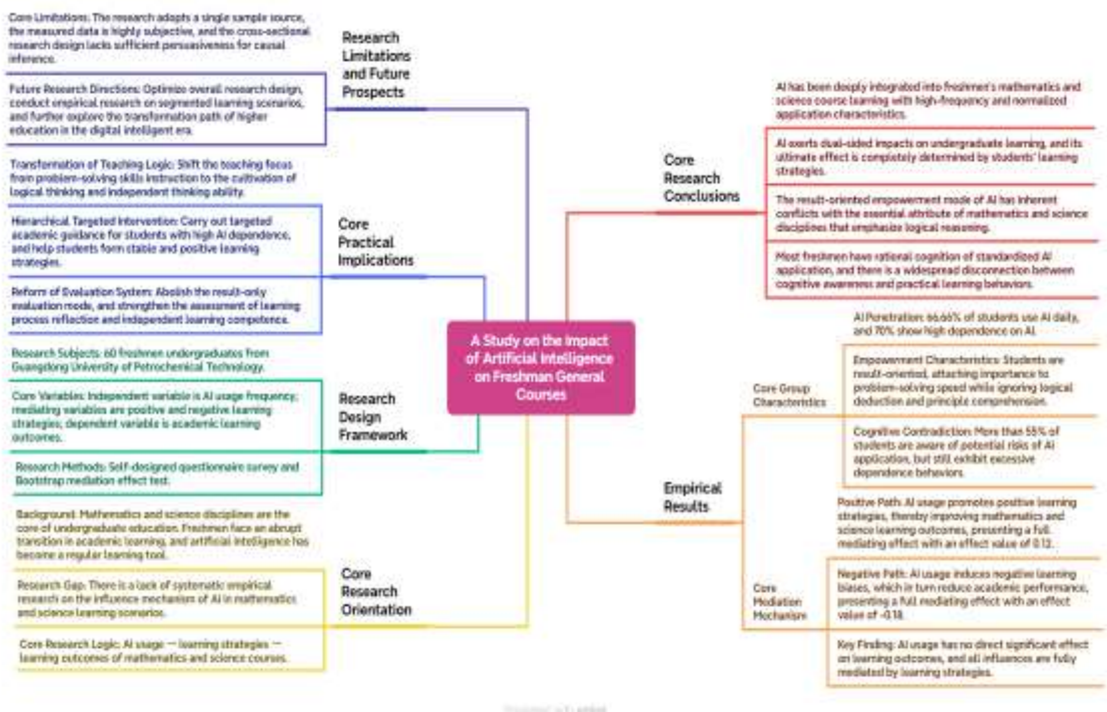


Figure 1: Mind Map of the Research on the Impact of AI on Freshman General Mathematics and Physics Courses

II. Literature Review

2.1 Impact and Coping Strategies of Generative AI on Mental Independence Among Freshmen

In their article "The Impact and Countermeasures of Generative AI on College Students 'Mental Autonomy" [1],XiuWen Liang and ShuXuan Chen argue that while generative AI enhances learning efficiency, it also exerts significant negative effects on students' mental independence. This concern is particularly acute for first-year undergraduates undergoing a critical cognitive transition. Generative AI tends to foster mental inertia and undermine independent thinking skills. Freshmen, transitioning from passive information reception to active knowledge construction, often bypass the essential cognitive processes—including problem decomposition, formula derivation, and logical reasoning—when relying excessively on AI for answers in mathematics and physics. This exacerbates "cognitive outsourcing" and gradually weakens their capacity for independent thinking. Additionally, generative AI may impair value judgment. With incomplete knowledge frameworks and limited life experience, freshmen struggle to verify the scientific validity of AI-generated content, especially when exposed to fragmented problem-solving approaches. Prolonged exposure to such methods may lead to flawed cognitive patterns and rigid thinking habits in foundational STEM studies. Finally, the technology worship fostered by generative AI may hinder innovative breakthroughs. The mathematical and scientific disciplines inherently emphasize logical innovation and divergent thinking. However, AI-generated content often exhibits templated and procedural characteristics. If freshmen treat such content as gospel truth, they risk being confined within algorithmically predetermined cognitive frameworks, hindering the development of critical thinking and original perspectives, thereby ultimately impeding the comprehensive growth of their scientific literacy and innovative capabilities.

The aforementioned analysis provides a theoretical foundation for this study to understand the psychological mechanisms underlying freshmen's use of AI in mathematics and physics learning. Notably, the introduction of the concepts of' mental inertia 'and' cognitive outsourcing' helps explain the observed negative learning biases in subsequent data analyses.

2.2 Research on the Impact of AI-Enabling Autonomous Learning on College Students' English Translation Skills

This study employs an empirical research methodology to systematically examine the complex relationships among AI empowerment, autonomous learning capabilities, and college students 'English translation skills. Using a sample of 336 English majors, the study collected data through multidimensional scales and standardized translation tests, employing regression analysis and Bootstrap mediation testing methods. The findings reveal that AI empowerment enhances translation skills through dual pathways: On one hand, AI stimulates students' strategic innovation and metacognitive monitoring abilities via personalized feedback and intelligent recommendations, thereby positively improving translation skills; on the other hand, the convenience of AI tools may induce tool dependence and cognitive inertia, creating a negative autonomous bias that inhibits translation performance. The study further demonstrates that positive autonomous ability serves as a significant positive mediating factor between AI empowerment and translation skills, while negative autonomous bias acts as a significant negative mediating effect, forming a competitive mediation relationship where one effect compensates for the other. Ultimately, the positive impact of autonomous ability dominates the overall influence of AI empowerment, highlighting that learners' active engagement and metacognitive monitoring constitute the core mechanism through which technological empowerment translates into skill enhancement.

The research's methodological framework, variable design, and analytical approach to mediating effects provide valuable reference for investigating the impact of generative AI on first-year undergraduate students' learning of fundamental mathematical sciences. Notably, it offers a transferable research paradigm for examining the mediating mechanisms between AI usage behavior, self-directed learning capabilities, and academic performance.

Unlike the aforementioned theoretical analyses grounded in the perspective of spiritual independence, the research conducted by Qu Tongfu and colleagues offers a practical empirical research paradigm worthy of reference.

2.3 Definition of Core Concepts

Generative Artificial Intelligence refers to AI systems based on large language models capable of generating text content according to user instructions (e.g., Deepseek, Doubao). In this study, generative AI specifically denotes conversational AI tools widely used by college students in mathematics and physics learning contexts (e.g., Deepseek, Doubao, Qianwen), with core functions including solving mathematical problems, answering physics concept queries, assisting in formula derivation, and providing problem-solving strategies.

Undergraduate freshmen are those who have just entered university life. At this stage, they undergo a transition from the "teacher-led" learning model in high school to "self-directed learning" in university, particularly in mathematics and physics, where they commonly face a "junctural challenge" characterized by a surge in knowledge volume, increased abstraction levels, and rigorous derivation requirements. These characteristics make first-year undergraduates one of the key groups studying the impact of AI technology—they are both active users of AI and the most vulnerable to its double-edged nature.

Public foundational mathematics and physics disciplines refer to compulsory basic mathematics and physics courses offered by higher education institutions to all undergraduate students, particularly those in science and engineering programs. These courses primarily include Advanced Mathematics and University Physics. Such disciplines exhibit the following distinctive characteristics: logical progression, with knowledge systems structured in a stepwise manner where earlier concepts serve as the foundation for subsequent learning; rigorous derivation, emphasizing formal reasoning starting from axioms and definitions, where the reasoning process itself constitutes the learning objective; and practice-dependent mastery, as conceptual internalization and skill acquisition require extensive independent practice and error correction. These features determine that both the "process" and the "result" are equally important in learning mathematics and physics, providing a unique context for examining the impact of AI tools.

Mathematical learning strategies refer to the behavioral patterns students exhibit when utilizing AI in their studies, encompassing two dimensions: active learning strategies (proactive exploration, reflective verification) and passive learning biases (tool dependency, cognitive inertia).

In this study, the effectiveness of mathematics and science learning is operationalized as students 'test scores, comprising two specific indicators: first, accuracy rates in routine assignments and tests; second, assessments of students' independent problem-solving abilities before and after AI intervention. The use of multidimensional metrics aims to distinguish between "task completion capabilities with AI assistance" and "true mastery levels without AI support," enabling a more comprehensive evaluation of generative AI's actual impact on freshmen's learning and retention of mathematical and scientific subjects.

III. Research Design

3.1 Research Background and Objectives

With the rapid advancement of generative AI technology, AI tools represented by DeepSeek have increasingly permeated higher education, particularly in the study of fundamental mathematical and scientific disciplines. A growing number of first-year undergraduates now utilize AI-assisted tools for previewing lessons, completing assignments, and reviewing material. However, systematic empirical research examining the actual mechanisms of generative AI in mathematics and science learning remains scarce in academia. On one hand, AI may enhance learning efficiency through real-time feedback and diversified explanations; on the other hand, excessive reliance could impair students 'independent thinking skills and lead to weak mastery of foundational knowledge. This study aims to systematically investigate the impact of generative AI on first-year undergraduates' mathematics and science learning by analyzing students' usage behaviors, dependency levels, cognitive attitudes, and self-reported learning outcomes, thereby revealing the dual effects of AI in this educational context.

3.2 Research Question

Based on theoretical analysis, this study proposes the following four core research questions:

First, the frequency and contexts in which first-year undergraduate students utilize generative AI in their mathematics and physics studies.

Second, what is students' perception of the effectiveness of AI-assisted learning, and to what extent do they rely on AI?

Third, what positive and negative impacts has the use of AI had on students' independent thinking skills, mastery of foundational knowledge, and learning transfer abilities?

Fourth, based on research findings, how should teaching strategies be designed to guide students in the rational use of AI?

3.3 Research Methods and Tools

This study employed questionnaire surveys as the primary data collection method. The self-designed structured questionnaire measured students 'AI-assisted mathematics and science learning across multiple dimensions: Part One included basic student information (gender, major); Part Two focused on AI usage behaviors, covering frequency and application scenarios; Part Three examined students' subjective perceptions of AI-assisted learning, including changes in proficiency levels before and after usage and their reliance on AI; Part Four analyzed learning strategies during AI use, categorized into positive strategies (active verification) and negative biases (direct adoption). The questionnaire questions balanced behavioral frequency, attitudinal tendencies, and self-evaluations, aiming to comprehensively capture students' learning characteristics in the digital and intelligent era.

In terms of variable operationalization, professional category, AI usage frequency, and usage scenarios serve as independent variables; dependence level and reflective behavior act as mediating variables; changes in mastery level serve as the dependent variable. The dependence level is measured using a five-level scale (very dependent, relatively dependent, general, not very dependent, completely not dependent). Both reflective behavior and direct adoption behavior are assessed using a five-point Likert scale, with options including "completely inconsistent," "basically inconsistent," "general," "basically consistent," and "completely consistent." To ensure validity and reliability, the initial questionnaire draft was designed based on existing research frameworks, reviewed and revised by experts in relevant fields, and refined through small-scale pilot testing to ensure clear and unambiguous wording.

Figure 2: Survey Questionnaire Mind Map

3.4 Data Analysis Methods

To address the aforementioned research questions, this study employed SPSS and PROCESS for data analysis. First, descriptive statistical analysis was conducted to examine the distribution characteristics of variables such as students' AI usage behavior, dependency levels, learning strategies, and mastery progression. Second, Pearson correlation analysis was used to assess the relationships among these variables. Finally, a mediation effect test was performed to investigate the mediating role of positive learning strategies and negative learning biases in the relationship between AI usage and mastery improvement. The study conclusions were derived based on these analyses.

3.5 Expected Results

The impact of generative AI on freshmen's self-directed learning abilities may manifest through two distinct pathways.

H1: Generative AI has a significant positive impact on the effective learning strategies of first-year university students.

On the positive front, the real-time Q&A and step-by-step explanation features of generative AI enable students to proactively explore diverse solutions when encountering challenges in mathematics and physics learning, thereby enhancing strategic innovation. Meanwhile, the logical reasoning prompts provided by AI help students promptly reflect on and adjust their learning strategies, fostering the development of metacognitive monitoring skills. This leads to the formulation of Hypothesis H1.

H2: Generative AI has a significantly positive impact on the negative learning biases among first-year university students.

From a negative perspective, the convenience offered by generative AI may lead students to seek answers directly, reducing independent thinking and fostering tool dependency. Prolonged reliance on such tools can induce cognitive inertia, diminish in-depth analysis of problem-solving logic, and hinder the development of independent problem-solving skills. This leads to the formulation of Hypothesis H2.

The effects of positive autonomy and negative autonomy bias on freshmen's mathematical learning skills may be entirely opposite.

H3: Active learning strategies significantly enhance the academic performance of first-year students in mathematics and physics subjects.

Students with high levels of strategic innovation and metacognitive monitoring abilities actively explore problem-solving approaches and excel at reflection and summarization in mathematics and physics learning, thereby enhancing their formula derivation and logical modeling skills. This leads to the formulation of Hypothesis H3.

H4: Negative learning bias exerts a significant negative inhibitory effect on the academic performance improvement of freshmen in mathematics and physics subjects.

Conversely, students who habitually rely on AI for answers often lack a deep understanding of fundamental concepts and struggle to solve variant problems independently. Their cognitive inertia leads them to neglect reflecting on incorrect answers and summarizing knowledge, making it difficult to transform fragmented knowledge into systematic problem-solving skills. This leads to the formulation of Hypothesis H4.

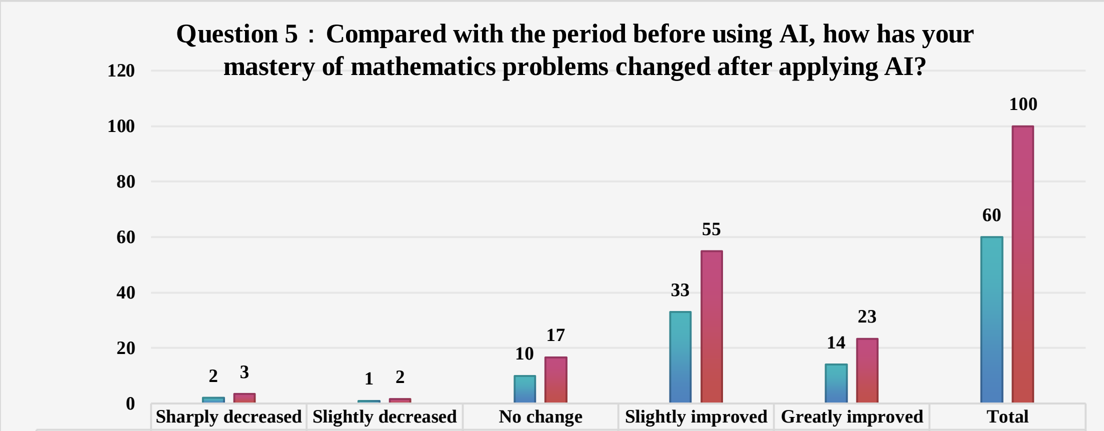
IV. Survey and Analysis

4.1 Questionnaire Results Analysis

Descriptive Statistical Analysis: This study collected 60 valid questionnaires, with female participants accounting for 60% and male participants for 40%. In terms of academic specialization, science and engineering disciplines accounted for 41.67%, economics and management disciplines for 41.67%, humanities and social sciences for 13.33%, and other disciplines for 3.33%, indicating a balanced sample structure conducive to cross-disciplinary comparative analysis. Regarding AI usage patterns, students averaged 3.72 points (out of 5) per week in utilizing AI for mathematical and scientific learning, with 66.66% reporting "use daily" or "use multiple times daily," while only 3.33% reported minimal usage—demonstrating that generative AI has become a routine auxiliary tool for freshmen in their academic pursuits. The most frequent AI applications included tackling homework challenges (65%), previewing new concepts (63.33%), and exam preparation (60%), suggesting that AI is primarily employed for immediate learning tasks rather than systematic knowledge construction processes.

Regarding learning strategies and dependency levels, data shows students exhibit high reliance on AI, with 70% describing themselves as "relatively dependent" or "very dependent," and 8.33% stating they "cannot solve problems without AI." Meanwhile, proactive learning strategies were demonstrated by 66.67% of students who "somewhat agree" or "fully agree" to actively reflect on AI-provided problem-solving approaches and verify them through alternative methods, scoring an average of 3.82—indicating most students possess metacognitive awareness and reflective skills. However, passive learning tendencies persist: 40% of students "somewhat agree" or "fully agree" to directly adopt AI solutions, with 15% "fully agreeing," averaging 3.28, reflecting widespread "tool dependency" among students—a finding consistent with literature discussions on "mental inertia" and "cognitive outsourcing." In terms of learning outcomes, 78.33% of students reported "slight improvement" or "significant improvement" in mastery after AI use (average score: 3.45 out of 5), reflecting generally positive evaluations, though 16.67% noted "no change" and 5% reported "degradation." Students recognized AI's greatest benefits in problem-solving speed (65%), formula memorization (60%), and pattern identification (56.67%), while lower acceptance was observed for understanding derivation processes (41.67%), suggesting AI's empowerment primarily focuses on "result acquisition" rather than "process comprehension." Moreover, students generally recognize the negative impacts of excessive reliance: 58.33% believe it diminishes independent thinking skills, 56.67% find themselves at a loss when encountering variant problems, and 55% feel their grasp of fundamental knowledge is inadequate. These findings align closely with the literature review's discussion on "mental rigidity" and "limited innovative breakthrough capacity."

4.2 Result Analysis of Key Variables



	Sharply decreased	Slightly decreased	No change	Slightly improved	Greatly improved	Total
Count	2	1	10	33	14	60
Percentage	3	2	17	55	23	100

Figure 3: Improvement in mastery of mathematical problems after AI application

Analysis of Question 5：78.33% of students reported a "slight improvement" or "significant improvement" in their mastery level after using AI, indicating that the vast majority recognize AI's empowering role in learning subjectively. This figure aligns with AI's high-frequency usage pattern (66.66% use daily), suggesting students continue employing AI precisely because they perceive enhanced learning outcomes. Despite the overall positive feedback, 16.67% reported "no change" and 5% indicated "degradation." This distribution highlights AI's heterogeneous impact: some students may experience diminished actual mastery due to over-reliance on AI, or AI itself fails to effectively address their learning challenges. Notably, this measure reflects students' self-perceived changes in mastery rather than objective test scores. Subsequent analyses reveal a positive correlation between proactive learning strategies and this variable (r=0.53) and a negative correlation between passive learning biases and it (r=-0.47), demonstrating strong consistency between students' self-perceptions and actual learning behaviors—validating the reliability of self-report data to some extent.

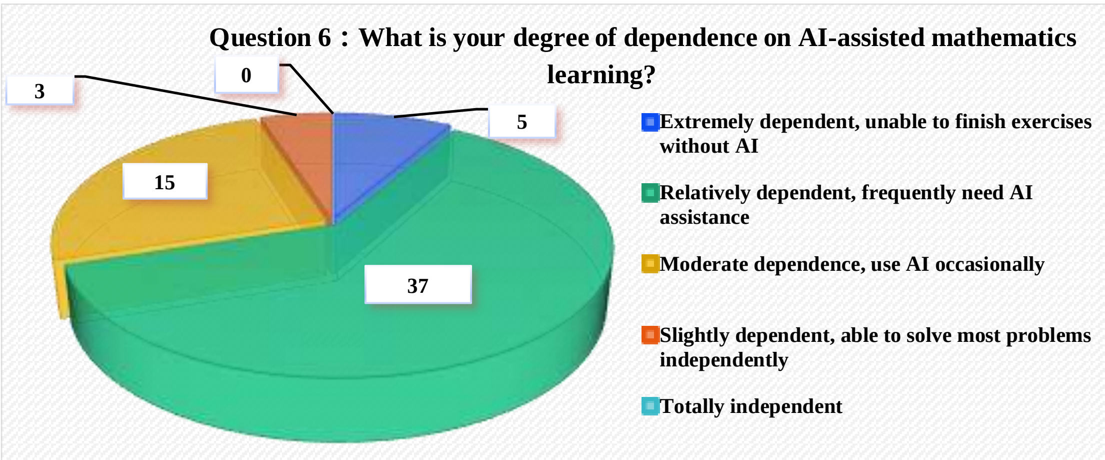


Figure 4: Dependence on AI-assisted learning

Analysis of Question 6：The prevalence of dependency is notably high. Seventy percent of students exhibit "moderate dependence" or "strong dependence," with 8.33% stating they "cannot solve problems without AI." This figure significantly exceeds the 5% in the "moderate dependence" category and the 0% in the "completely independent" group, indicating that AI dependency has become widespread among students, with some developing deep reliance. Data from Question 3 (AI usage frequency) reveals that 66.66% of students "use AI daily" or "multiple times daily" —a correlation between frequent usage and high dependency, demonstrating AI's evolution from an auxiliary tool to an essential resource for some learners. A polarization trend emerges: The high-dependency group (strong and moderate dependents) comprises 42 students (70%). Notably, no students reported being "completely independent," highlighting AI's pervasive integration into mathematics and science education. A significant numerical gap between high-and low-dependency groups suggests most students lack sufficient confidence in independent problem-solving, with 8.33% (five students) confirming they "cannot solve problems without AI" —making this group the highest-risk subgroup under AI's "double-edged sword" effect. Data from Question 8 (15% of students "completely adopt answers directly") indicates these students likely suffer from severe "cognitive outsourcing," potentially compromising their independent problem-solving abilities—a clear reflection of challenges in higher education content mastery.

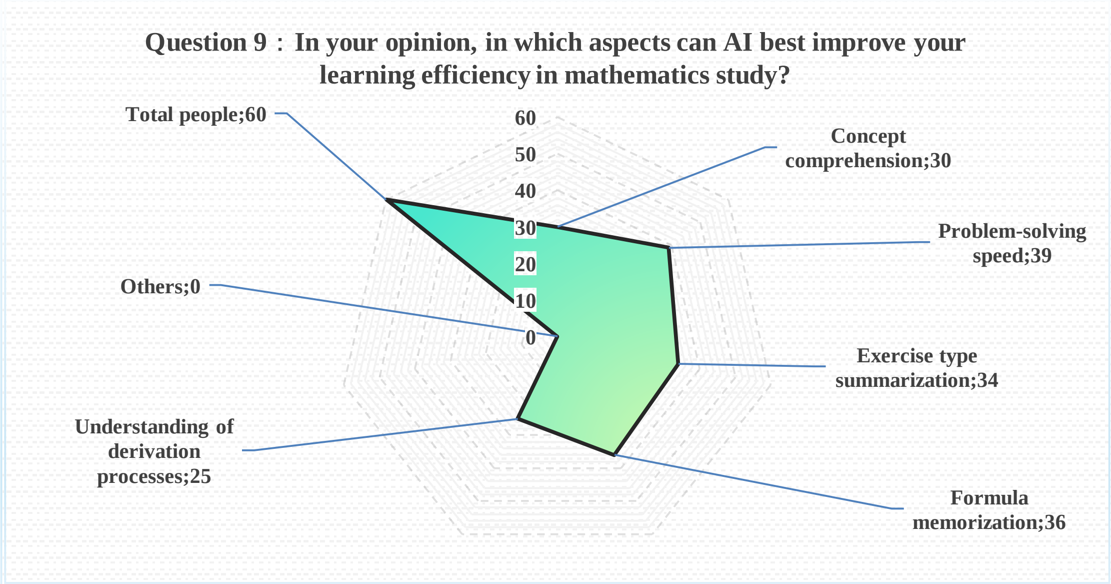
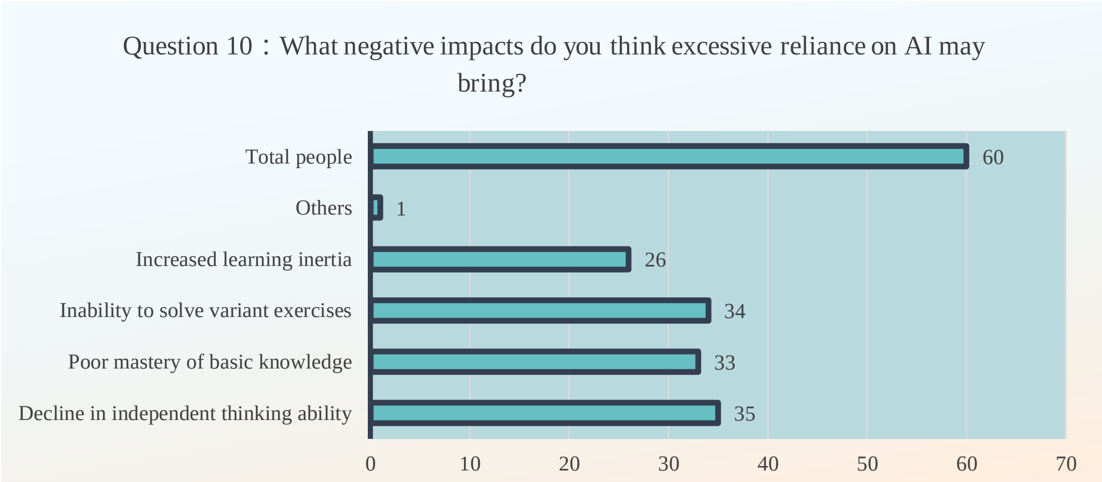


Figure 5: AI's understanding of learning enhancement

Analysis of Question 9：Students rated AI's improvements most notably in "problem-solving speed" (65%), "formula memorization" (60%), and "question type summarization" (56.67%), while showing the lowest satisfaction with "derivation process comprehension" (41.67%). The ranking is: problem-solving speed> formula memorization> question type summarization> concept understanding> derivation process comprehension.

This distribution reveals the empowering characteristics of current AI tools in student usage. Strengths include providing quick answers, offering ready-made formulas, and summarizing question patterns—falling under the dimensions of "result acquisition" and "efficiency enhancement"; weaknesses involve assisting in understanding the derivation process—related to "process comprehension" and "thinking construction." Students perceive AI advantages primarily in reducing cognitive load and improving task completion efficiency, rather than deepening understanding of the subject's essence. This contrasts with the overall evaluation in Question 5 (mastery improvement), where 78.33% of students reported that AI enhanced their mastery—while students generally felt they "learned better," this improvement was more evident in "working faster" than in "deeper understanding."



	Decline in independent thinking ability	Poor mastery of basic knowledge	Inability to solve variant exercises	Increased learning inertia	Others	Total people
Count	35	33	34	26	1	60

Figure 6: Perceptions of AI's Negative Impacts

Analysis of Question 10：Students generally demonstrate risk awareness, with over half acknowledging these negative effects—a clear indication that they do not blindly rely on AI but possess a clear understanding of its excessive usage risks. This finding contrasts sharply with the 70% dependency rate reported in Question 6. While students exhibit high practical dependence on AI, they cognitively recognize the potential hazards of such reliance. This tension between cognition and behavior provides a strategic entry point for instructional interventions, as students' risk awareness can serve as the cognitive foundation for modifying their usage habits. Their risk perception focuses on critical thinking and transfer skills. Options like "declined independent thinking ability," "inability to handle variant problems," and "weak grasp of foundational knowledge" collectively highlight two core competencies: independent reasoning and knowledge transfer capabilities—precisely the essential literacy for STEM learning. STEM education demands not only mastery of knowledge points but also logical reasoning and the ability to apply knowledge flexibly. Students themselves recognize that excessive reliance on AI may erode these fundamental competencies. The selection rate for the option "Increased learning inertia" was 43.33%. Although still substantial, this figure was lower than that of the first three options. This discrepancy may indicate that students perceive "inertia" less intuitively than "declining ability" —since ability decline can be verified through testing, whereas inertia is an internal state difficult to self-detect. Some students might interpret "dependence on AI" as "efficient learning" rather than a manifestation of inertia, suggesting divergences between their understanding and researchers '. It also reflects students' failure to establish a clear connection between "AI dependence" and "reduced learning initiative". Meanwhile, students' risk perceptions align with their behavioral patterns: The risk perceptions identified in Question 10 correspond to the negative learning biases detected in data analysis. Their concern about "declining independent thinking skills" directly stems from answer selection habits, while their anxiety regarding "being unable to tackle variant problems" is precisely the inevitable consequence of "directly adopting answers" as observed in Question 8, leading to weak foundational knowledge.

4.3 Intermediary Test

Variable settings: Independent variable (X): AI usage frequency. Mediating variables: Positive learning strategies (M1) and Negative learning bias (M2). Dependent variable (Y): Mathematical learning outcomes. Method: Bootstrap analysis performed 5000 times with a 95% confidence interval.

The regression analysis results indicate that AI usage frequency has a significant positive predictive effect on positive learning strategies ($\beta=0.28$, $p<0.05$), confirming Hypothesis H1; it also shows a significant positive predictive effect on negative learning biases (β=0.41, $p<0.001$), confirming Hypothesis H2; positive learning strategies exert a significant positive influence on mathematics learning outcomes (β=0.53, $p<0.001$), confirming Hypothesis H3; while negative learning biases have a significant negative impact on mathematics learning outcomes (β=-0.47, $p<0.001$), confirming Hypothesis H4.

Table 1: Mediation Test

Intermediary Path	Indirect Effect Value	95% confidence interval	Agent Type	conspicuousness
AI Implementation → Active Learning Strategies → Learning Outcomes	0.12	[0.03, 0.24]	Fully Intermediary	notable
AI usage → Negative learning bias → Learning outcomes	-0.18	[-0.32, -0.07]	Fully Intermediary	notable
Total Indirect Effect	-0.06	[-0.20, 0.08]	—	Not significant
gross effect	0.15	[-0.07, 0.36]	—	Not significant

The frequency of AI usage has no direct impact on learning outcomes in mathematical studies; its effects are mediated entirely through two competing pathways: positive mediation via proactive learning strategies and negative mediation via passive learning biases, with the ultimate effectiveness determined by learning strategies.

V. Conclusion and Recommendations

5.1 Conclusion

This study employed a sample of 60 first-year undergraduate students from Guangdong University of Petrochemical Technology, employing questionnaire surveys and mediation effect analysis to systematically elucidate the mechanisms through which generative AI influences their learning of foundational mathematical and scientific subjects. The key findings are as follows: Generative AI has become deeply integrated into the entire learning process of first-year students, with its usage exhibiting high frequency and routine characteristics—over 60% of students utilize AI for daily learning support, while 70% develop significant dependence on it, primarily in immediate learning scenarios such as homework completion, previewing, and exam preparation. The impact of AI on mathematics and science learning is a classic "double-edged sword," with its effects on learning outcomes mediated entirely through two competing pathways: positive learning strategies act as a positive mediator, whereas negative learning biases serve as a negative mediator. Learning strategies are the decisive variable determining the ultimate effectiveness of AI usage, as AI itself does not directly or significantly influence learning outcomes. Students 'perception of AI's empowerment is distinctly results-oriented—they highly recognize its value in improving problem-solving speed and formula memorization, but show minimal appreciation for its role in understanding derivation processes—a contrast that fundamentally conflicts with the core principle of mathematics education, which emphasizes equal importance of both process and outcome. Despite widespread awareness of the risks associated with excessive AI dependence, first-year students exhibit significant "easier said than done" behavior, creating a stark tension between risk perception and actual usage patterns—this gap constitutes the primary focus for instructional interventions in mathematics education.

5.2 Recommendations

Based on the research findings, the following core strategies are proposed: First, reconstruct the teaching logic by shifting the focus to cultivating logical thinking, designing AI-integrated reflective tasks that guide students from seeking answers to emphasizing the learning process, thereby transforming AI from a problem-solving tool into a cognitive partner; Second, implement tiered interventions with targeted support for high-risk groups exhibiting excessive AI dependence, resolving cognitive-behavioral conflicts and solidifying positive learning strategies; Third, reform the assessment system by moving beyond outcome-oriented evaluation, increasing the weight of formative assessments, conducting AI-free independent problem-solving tests, and focusing on core mathematical and scientific literacy; Fourth, provide specialized guidance to teach students how to scientifically utilize AI in mathematical and scientific contexts, fostering critical thinking and standardizing AI usage practices.

VI. Acknowledgements

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