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Research on the Practical Path of Generative AI Empowering Teaching Reform of Probability and Mathematical Statistics in Chinese Tertiary Education

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Abstract: Probability and Mathematical Statistics is a fundamental public mathematics course widely offered to science, engineering, and economics–management students in Chinese universities. [1] Driven by global educational digitalization and national initiatives of emerging engineering and emerging liberal arts, traditional teaching has been constrained by overemphasis on abstract theories, insufficient practical instruction, limited personalized support, and oversimplified assessment systems. These shortcomings severely hinder the cultivation of data literacy and statistical reasoning abilities required by contemporary talent development. As an advanced technological tool, generative artificial intelligence presents great potential for innovating instructional design and improving learning effectiveness in higher mathematics education. Based on authoritative data from the Ministry of Education of China, national teaching surveys, and institutional teaching practices, this study identifies core challenges in current probability and statistics education, analyzes the transformative value of generative AI for teaching improvement, and proposes a systematic reform framework covering curriculum optimization, pedagogical innovation, practical training enhancement, and diversified assessment construction. This paper also clarifies ethical boundaries and practical principles for the responsible integration of generative AI. The conclusions and pathways are intended to provide reliable, evidence-based references for advancing the high-quality development of probability and statistics teaching in Chinese tertiary education.

Keywords: Generative AI; Probability and Mathematical Statistics; Teaching Reform; Blended Learning; Educational Digitalization; Tertiary Education

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1. Introduction

1.1 Research Background and Importance

In the era of big data and artificial intelligence, statistical thinking, data analysis capability, and stochastic modeling competence have become essential for high-level professional talents. Probability and Mathematical Statistics, which studies the statistical laws of random phenomena, is characterized by both theoretical rigor and extensive practical applicability, thus playing a fundamental and instrumental role in undergraduate education. According to the Report on the Construction of Public Mathematics Courses in Chinese Universities (2025) issued by the Steering Committee for Mathematics Teaching in Higher Education, the annual enrollment of probability and statistics courses exceeds 5 million students, making it one of the

most influential foundational mathematics courses in China.

Nevertheless, long-standing deficiencies persist in instructional practice. First, conceptual abstraction leads to learning difficulties. The 2025 Undergraduate Teaching Quality Annual Report of the University of Science and Technology of China shows that 62.3% of students consider the course overly abstract and difficult to master. Second, instructional methods remain largely lecture-dominated. A bibliometric review in Educational Progress (2023) indicates that traditional direct instruction accounts for 73.5% of class time.[4] Third, practical training is inadequate. A survey conducted by the National Emerging Engineering Education Expert Group (2024) reveals that only 31.7% of universities provide systematic training in Python, R, or other statistical software. Fourth, assessment relies excessively on final examinations, resulting in incomplete and biased evaluation of student ability.

Against this backdrop, China has accelerated its national educational digitalization strategy, building the world's largest online tertiary education resource system. The National Educational Digitalization Strategy Action Implementation Report (2025) notes that the Smart Education of China platform hosts 145,000 high-quality university courses, with 68.7% of tertiary education institutions adopting AI-assisted teaching.[2] Generative AI's capabilities in content generation, intelligent tutoring, simulation visualization, and personalized resource recommendation offer effective solutions to traditional instructional bottlenecks,[7] which prompts this study to explore systematic pathways for generative AI to empower the teaching reform of Probability and Mathematical Statistics.

1.2 Research Objectives

This study identifies core challenges in current Probability and Mathematical Statistics teaching in Chinese tertiary education, analyzes generative AI's transformative value in optimizing teaching and improving learning effectiveness, and proposes a systematic, operable reform framework. Specifically, it explores integrating generative AI into curriculum restructuring, pedagogical innovation, practical training enhancement, and assessment optimization, while clarifying ethical boundaries and practical principles of AI integration. Ultimately, it aims to provide evidence-based references for advancing the high-quality development of the course and cultivating talents with strong data literacy and statistical reasoning abilities.

1.3 Data Source Description

This study uses authoritative data from China's Ministry of Education, national teaching surveys, and key university teaching practices. Specific sources include the 2025 Report on the Construction of Public Mathematics Courses in Chinese Universities, the National Educational Digitalization Strategy Action Implementation Report (2025), teaching quality reports from institutions like the University of Science and Technology of China, Nankai University, and Wuhan University, as well as relevant academic journals and surveys. These sources ensure the research's authority and reliability by providing accurate data on course enrollment, student learning difficulties, teaching methods, practical training conditions, and AI application effects.

2. Practical Value of Generative AI in Probability and Statistics Education

2.1 Reducing Cognitive Load for Abstract Concepts

Core concepts such as probability distributions, hypothesis testing, and confidence intervals are inherently abstract, making them difficult to convey through conventional blackboard derivation. Generative AI enables dynamic simulation, visual experimentation, and contextualized case illustration to lower the learning threshold. Nankai University's 2024 Intelligent Teaching Pilot Report shows AI-assisted visualization of the central limit theorem and stochastic processes improved students' conceptual comprehension efficiency by 47%.

2.2 Enabling Precise and Personalized Instruction

The 2025 Annual Operation Report of the Smart Education of China Platform notes that 64.5% of Chinese universities have deployed intelligent teaching systems. By analyzing learning behavior data, generative AI identifies knowledge gaps, delivers tailored exercises, and provides adaptive tutoring, addressing the limitations of one-size-fits-all classroom teaching and helping students target their weaknesses.

2.3 Enriching Localized and Contextualized Teaching Resources

The 2025 National MOOC Development Report shows China has 97,000 MOOCs, ranking first globally.[3] Generative AI

supports the rapid production of case libraries, experimental datasets, code templates, and analytical materials, enabling instructors to develop localized resources aligned with industrial needs and national development contexts, with targeted cases for different majors to strengthen the link between theory and practice.

2.4 Improving Classroom Engagement and Interaction Efficiency

Wuhan University's 2024 Smart Teaching Construction Report shows integrating AI teaching assistants increased student classroom participation from 38% to 82% and tripled interactive frequency. By automating repetitive tasks like questioning and grading, generative AI allows instructors to focus on higher-order instruction and reasoning guidance, transforming students from passive knowledge recipients to active participants.

3. Major Challenges in Current Probability and Statistics Teaching

3.1 Overemphasis on Theoretical Derivation at the Expense of Application

Mainstream textbooks prioritize formulaic deduction and theorem proving, with limited connection to real-world scenarios, big data analytics, or industrial applications. A 2026 national survey in China University Teaching indicates 71.2% of students struggle to apply knowledge to practical problems, undermining their learning motivation and practical ability.[5]

3.2 Dominance of Traditional Pedagogy and Weak Student Initiative

The 2024 National Observation Report on Mathematics Classroom Teaching in Local Universities shows lecturing occupies over 70% of class time, with insufficient inquiry-based, interactive, or cooperative learning activities. This leaves students passive, depriving them of opportunities for independent thinking and discussion, which hinders the cultivation of innovative thinking and problem-solving abilities.

3.3 Insufficient Practical Training and Software Proficiency

The 2024 National Survey on Experimental Teaching of Basic University Courses reveals that only 29.4% of local universities have virtual simulation platforms for probability and statistics. Many courses still rely on manual calculation, leaving students unprepared for data-intensive professional environments—despite proficiency in statistical software like Python and R being essential for modern talents.

3.4 Simplified Assessment and Lack of Process-Based Evaluation

Zhengzhou University's 2024 Curriculum Assessment Reform Survey notes final written examinations often account for over 70% of the overall grade, with insufficient attention to homework, practical projects, data analysis reports, or in-class participation. This simplified method focuses solely on final outcomes, ignoring the learning process and students' comprehensive ability improvement.

4. Practical Paths for Generative AI to Empower Teaching Reform

4.1 Curriculum Restructuring: A Three-Dimensional Framework of "Theory + AI + Application"

Guided by the Ministry of Education's 101 Plan for Mathematics Majors (2024), the course curriculum is restructured into a "Theory + AI + Application" three-dimensional framework, integrating theoretical knowledge, technical tools, and practical applications.

First, streamline theoretical content by reducing complicated proofs and focusing on conceptual understanding and methodological application, using generative AI for visualized interpretation and dynamic simulation of core theories. Second, integrate computational tools: generative AI automatically generates Python scripts, data processing templates, and statistical simulation programs to enhance students' practical data analysis abilities. Third, incorporate localized professional cases—household consumption and regional economic data for economics/management majors, industrial quality inspection and meteorological prediction for science/engineering, and social surveys and rural revitalization data for humanities/social sciences—tailored by generative AI to boost curriculum relevance.

4.2 Pedagogical Innovation: Whole-Process Blended Learning

Generative AI enables a whole-process blended learning model covering pre-class, in-class, and post-class, breaking traditional classroom limitations and integrating online and offline teaching.[8]

Pre-class: AI provides preview materials, concept maps, and diagnostic exercises, with automated grading and learning

analytics to help instructors identify key and difficult points (Lanzhou University of Technology, 2024, reported a 65% improvement in pre-class targeting accuracy). In-class: AI generates dynamic simulations, real-time quizzes, and inquiry-based tasks to boost participation from approximately 40% to over 80%.[6] Post-class: AI offers round-the-clock intelligent Q&A, targeted assignments, and error feedback, with a 2025 Guangdong report recording a 60% improvement in students' after-class problem-solving efficiency.

4.3 Practical Training Enhancement: A Three-Tier Practical System

Generative AI supports a three-tier practical training system, progressing from basic operation to innovative exploration to comprehensively enhance students' practical ability and innovative thinking.[9]

Basic operation: AI-generated tutorials and standardized datasets for data cleaning, statistical plotting, and hypothesis testing, helping students master statistical software basics. Comprehensive projects: Contextualized tasks (e.g., consumption structure analysis, urban air quality assessment) requiring complete statistical reports, with AI providing templates and data support. Innovative exploration: Integration with competitions like the National College Students Mathematical Modeling Contest and Challenge Cup, with AI offering case analysis and technical guidance to strengthen data modeling and innovation.

4.4 Assessment Optimization: A Diversified Process-Based Evaluation System

Generative AI supports a three-dimensional evaluation system combining process, outcome, and competency evaluation to comprehensively, objectively, and fairly assess students' comprehensive literacy.

Process evaluation (40%): AI automatically records and quantifies previews, homework, classroom performance, and experimental tasks, emphasizing the learning process. Outcome evaluation (30%): Mid-term and final examinations use AI-generated test papers and automated grading, ensuring scientificity and fairness. Competency evaluation (30%): AI assists in evaluating practical projects, data analysis reports, and group presentations, providing objective references.

5. Precautions for Integrating Generative AI into Teaching

5.1 Uphold the Instructor as the Primary Guide

Generative AI is only an auxiliary tool and must not replace instructors in knowledge construction, logical reasoning, or value guidance. The "people-oriented and teacher-led" principle must be strictly observed (Ministry of Education, 2025), with instructors leading curriculum design, teaching organization, and student guidance, while using AI to handle repetitive tasks and improve efficiency.

5.2 Strengthen Data Ethics and Academic Integrity

Universities should formulate clear AI usage norms, define boundaries for assignments and reports, prevent AI-generated plagiarism, and cultivate students' integrity. Instructors should guide students to use AI as a learning tool (not an assignment shortcut) and foster independent thinking and innovation.

5.3 Enhance Instructors' Digital Literacy and Integration Competence

Per the 2025 National Report on University Teachers' Digital Literacy, universities should strengthen systematic training to improve instructors' ability to integrate AI into curriculum design and instruction. Instructors need to master AI's basic functions and design AI-assisted teaching activities tailored to the course's characteristics.

5.4 Avoid Technological Formalism

Instruction should prioritize conceptual understanding, logical thinking, and applied ability over technological spectacle. AI deployment should be realistic, targeted, and scalable to institutional conditions, focusing on practical teaching needs rather than blind technological novelty.

Conclusion

Against China's educational digitalization strategy, generative AI provides robust technical support for Probability and Mathematical Statistics teaching reform. Restructuring the curriculum, innovating pedagogical models, strengthening practical training, and optimizing assessment effectively alleviates long-standing issues like over-abstraction, weak application, insufficient personalization, and simplistic evaluation.

The Smart Education of China platform has over 178 million users (2025), laying a solid foundation for AI-enhanced

mathematics teaching. Moving forward, universities should deepen the integration of AI and mathematics education, refine implementation pathways, and leverage technology to serve talent development—cultivating high-quality innovative professionals with strong data literacy and statistical competence to support the construction of a strong educational nation.

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Conflict of Interests

The authors declare that there is no conflict of interest regarding the publication of this paper.

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