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The Application of Empowering AI in Advanced Mathematics Teaching

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Abstract: This paper systematically discusses the application paths and practice models of AI technology in advanced mathematics teaching in universities, with emphasis on the reform of advanced mathematics teaching assisted by AI in the three stages of "before class, during class, and after class". Intelligent learning diagnosis enables AI to achieve accurate pre-class preview; real-time interaction and intelligent assistance in the classroom allow for a better teaching and learning experience; and intelligent grading and personalized tutoring can extend the learning effects after class. The paper discusses the concrete implementation and effects of AI in the context of advanced mathematics instruction and identifies potential issues, such as technological limitations, data security, and changes in the role of the teacher. With the support of AI technology, advanced mathematics teaching is no longer "experience-driven" but becomes "data-driven", no longer "standardized teaching" but "personalized learning" and opens up new possibilities for improving the quality of advanced mathematics education.

Keywords: Advanced Mathematics; AI; Smart Teaching; Personalized Learning; Teaching Reform.

1. Research Background and Objectives

Pain Points of Traditional Advanced Mathematics Teaching. Advanced mathematics is one of the essential public basic courses for science, engineering, economics and management majors. It plays a core role in cultivating students' logical thinking, abstract thinking and comprehensive problem-solving ability. In the traditional advanced mathematics teaching, teachers are usually the main body and mainly impart knowledge points in the process of teaching, without considering the individual differences of students, so that some students will gradually lose interest in mathematics learning because of the difficulty of the knowledge points. Besides, traditional teaching methods have obvious shortcomings in the aspects of resource integration, interaction and teaching evaluation which cannot meet the requirements of modern education for efficiency and individualization. In this context, AI technology's incorporation into advanced mathematics education is an inevitable trend [1].

Dual Background of Policy and Technological Development. AI technology is still on the rise and is rapidly penetrating the education sector. In 2025, the Ministry of Education and eight other departments issued the *Opinions on Accelerating the Digitalization of Education*, which clearly puts forward the suggestion of "promoting AI to empower educational reform", "accelerating the construction of AI educational large models", and "integrating AI technology into all aspects and the entire process of education and teaching". In response to this policy guidance, various universities have carried out concrete explorations and practice on integrating AI into advanced mathematics classes and have provided solid policy support and practical foundation for digital transformation of advanced mathematics teaching across the country.

Research Objectives of This Paper. This paper systematically reviews the application models of AI in advanced mathematics teaching in the pre-class, in-class and post-class stages, analyzes the actual effects of AI-empowered teaching based on real implementation cases from multiple universities across the country, objectively lists the various practical problems faced in the implementation of the technology, and provides practical reference and theoretical basis for the digital teaching reform of advanced mathematics in universities nationwide.

2. Applications of AI in the Pre-class Preparation Stage

Pre-lesson planning is the beginning of the closed loop of advanced mathematics teaching, and the quality of advanced mathematics pre-lesson

preparation directly determines the teaching effect of classroom and students' learning effect. The traditional pre-class model is completely based on teachers' personal experience in judging students' knowledge base and learning needs. Lesson preparation is based on personal accumulation and resources are limited and not well targeted. AI optimizes pre-class work in three aspects: learning diagnosis, intelligent lesson preparation and tiered preview content push.

Intelligent Learning Diagnosis and Construction of Refined Digital Student Profiles. By combining multi-dimensional data, including students' learning history, pre-test responses, and even behaviors of online learning, AI systems automatically generate refined learner profiles, and accurately pinpoint the knowledge deficits and ability gaps of each student. The "Zhida Tengfei" mathematics large model developed by the Shandong National Center for Applied Mathematics, for instance, can carry out high-precision learning diagnosis. Through the data, teachers can accurately understand the overall learning level of students and the differences among students, and scientifically set teaching objectives and the difficulty level of classroom teaching.

Intelligent Lesson Preparation Assistance and Efficient Assembly of Complete Teaching Resources. AI based on generative large models can rapidly search, integrate and recommend high-quality and high-value resources related to teaching contents, such as teaching videos, case materials, and exercise banks, etc., and provide suggestions for use. In terms of content generation, intelligent lesson preparation assistants based on large language models can rapidly prepare teaching outlines, teaching designs and courseware content based on the course syllabus and teaching needs. Teachers can flexibly adjust their instructions according to course needs, ensuring the completeness and coherence of the teaching content. In the AI-assisted smart course construction training at the South China University of Technology, the pre-class lesson preparation module emphasized the practical methods of intelligent lesson preparation and the construction of an AI question bank, enabling teachers to utilize AI tools to generate standardized lesson plans with one click, high-quality teaching cases, courseware frameworks, and classroom interaction plans. Teachers can also easily create test papers based on the existing teaching materials, including current course materials, key knowledge points, lecture videos etc., to effectively reduce the preparation time and simplify the lesson preparation process. Shenyang Aerospace University's "Shenhang Zhishu" (Shenhang Smart Mathematics) AI-assisted teaching system adopts a three-layer decoupled model of model, engine, and application to realize the efficient integration of the teaching process with AI large models like DeepSeek. The teachers can enjoy the use of AI functions without altering their teaching behavior, achieving a "seamless intelligent upgrade". Experience reveals that it can not only enhance the efficiency of teachers' lesson preparation, but also promote the overall improvement of teaching quality, and provide strong support for the blended teaching reform of advanced mathematics teaching [2].

Tiered Push of Personalized Preview Content to Implement Teaching in Accordance with Students' Aptitude [3]. In the context of mathematics classes, pre-class preview is an important part of learning advanced mathematics well and a bridge connecting the pre-class and in-class stages. Combining knowledge graphs can further optimize the recommendation strategy for preview resources, which is another advantage of AI technology. Knowledge graph can be used to systematically model the content of the advanced mathematics course, so that the scattered knowledge points are connected to form a complete knowledge network [4]. According to learning profiles, AI pushes preview materials to students: for low-performing students who have low levels of basic knowledge, it pushes videos explaining basic concepts and introductory exercises to consolidate basic knowledge; for high-performing students with surplus capacity, it pushes extended reading materials and comprehensive, higher-level and more difficult exercises. The preview content is intelligently pushed to students, so that students can familiarize themselves with the knowledge framework in advance, and fully prepare for classroom learning. With smart preview push, teaching in accordance with students' aptitude is no longer an abstract educational concept but a standardized operation that can be implemented in the pre-class stage.

3. Multiple Applications of AI in the Core Stages of Classroom Teaching

In order to solve the problems that are prominent

in traditional classrooms, such as monotonous interaction forms, delayed learning feedback, difficulty in understanding abstract mathematical concepts, the limitation of binary teacher-student interaction, AI has built a new "teacher-student-machine" three-party interactive classroom, so as to improve the classroom teaching quality.

Real-Time Interactive Assessment and Dynamic Adjustment of the Teaching Pace. Smart teaching platforms like Rain Classroom and Xuexitong with the support of artificial intelligence, can be used for diversified modes of interaction, such as in-class Q&A, quick-answer, online voting, group inquiry task, and real-time thematic discussion [5]. In the lecture, teachers can release in-class mini-quizzes anytime during the lecture and the system can collect the answering data of the entire class in real-time and present it in an intuitive manner, showing the students' mastery of each knowledge point. Teachers can flexibly adjust the key and difficult points of the lecture, and the pace of teaching based on the data. The platform can automatically create a classroom mind map, a complete teaching summary and standardized lecture notes after the class, enriching classroom forms and helping to better enliven the classroom atmosphere.

Round-the-Clock AI Teaching Assistants Undertake Repetitive Basic Teaching Work. Guangzhou University has developed a *Full-Chain Intelligent Agent Collaboration System for the Teaching, Learning and Assessment of Advanced Mathematics*. With six intelligent agents and a "five-in-one" teaching resource system, the university has developed an online intelligent learning companion that can provide 24-hour service. In the classroom, AI teaching assistants can handle simple and repetitive tasks in real time, such as knowledge point retrieval, instant answer to questions, guidance on problem-solving methods, etc., freeing teachers from a large number of simple Q&A tasks and enabling them to focus on guiding higher-order mathematical thinking and in-depth inquiry-based teaching. Based on the existing relevant research, it can be seen that generative artificial intelligence has advantages that traditional digital tools cannot match in the aspects of teaching assistance, auxiliary assessment of teaching, course design, etc., and can provide new opportunities for the transformation of classroom teaching.

Visualization Tools That Resolve the Difficulties of Mathematical Abstraction. Abstractness is the greatest difficulty in mastering advanced mathematics. AI visualization tools can help to make the content more visual, interactive, and intuitive, making it more accessible for students. AI technology can be used to create virtual experimental environments, which can help students learn about abstract concepts. There is much content in advanced mathematics that requires visualization, such as changes of function graphs, the application scenarios of calculus, the construction of spatial geometric models and so on, and it is hard for students to get a deep understanding of them only from the derivation of formulas and the two-dimensional graphic display [6]. For instance, in the topic of limits, dynamic images are able to intuitively exhibit the whole process of sequences and functions approaching a certain value infinitely; in the topic of multivariable calculus, three-dimensional dynamic models are able to intuitively present the abstract content of spatial surfaces, gradients and directional derivatives. Teaching practice of linear algebra visualization shows that making abstract mathematical knowledge concrete and tedious logic vivid can greatly improve students' abstract mathematical thinking ability, logical derivation ability and mathematical modeling application ability.

Reconstructing the "Teacher-Student-Machine" Triadic Interactive Classroom Model. The traditional single binary "teacher-student" interaction model has been transformed into a triadic collaborative interaction system with the introduction of AI into the classroom [7]. The role of teachers has changed from the only provider of knowledge output to the designer, organizer and thinking guide of classroom learning. The students have changed from passive listeners to active subjects of learning, who explore and think independently. AI performs various roles like collecting and analyzing data, providing immediate learning feedback and personalized learning assistance based on each student's data. This model reconstructs the relationship between teaching and learning at the fundamental level, shifting the focus of classroom teaching from the mere explanation of formulas and exercises to the all-round cultivation of students' mathematical thinking, comprehensive application awareness, and independent inquiry ability.

4. Precision Applications of AI in the Post-Class Consolidation Stage

Review and practice after class is an important

link to consolidate and enhance knowledge and skills, and to assess teaching effectiveness. The traditional post-class model usually has these issues: high workload of homework marking, hard to achieve one-on-one personalized tutoring, and learning feedback is seriously delayed. The application of AI in post-class teaching is transforming the extensive and unified teaching model to the precise and tiered teaching method, primarily manifested in three aspects:

Intelligent Homework Grading and Comprehensive Learning Diagnosis Reports. The application of AI in grading advanced mathematics homework relies mainly on image recognition and natural language processing technologies, allowing for automatic grading and personalized feedback on students' written work [8]. In advanced mathematics, grading of computational and proof problems has always been a time-consuming task. AI intelligent grading systems can complete computational and proof problems step-by-step and precisely recognize calculation errors and logical loopholes, clearly mark the reasons for the errors, and can also detect duplicate and plagiarized assignments at the same time. The "Shuni Zuiling" intelligent grading software was independently developed by students of the School of Mathematics at Renmin University of China, designed to meet the grading requirements of all question types in advanced mathematics and linear algebra. AI grading is not just about scoring; it also has learning diagnosis functions. It automatically generates a learning analysis report for the whole class, clearly highlighting the common knowledge weaknesses of the entire class, enabling teachers to achieve a comprehensive intelligent teaching closed-loop of "lesson preparation – classroom teaching – teaching reflection" to further make targeted improvements on weak points.

Adaptive Tiered Exercise Training to Provide Different Questions for Different Students. The Shandong National Center for Applied Mathematics' "Zhida Tengfei" platform has an intelligent question-generation module which can generate differentiated questions according to the individual learning profile of each student. AI teaching platforms, based on large question banks and AI algorithm engines, can assign tiered homework, generating different papers for different students, such as through Rain Classroom. The system tracks students' performance in real time and dynamically adjusts the difficulty, question types and pace of exercises so that each student practices within their own "zone of proximal development". This fundamentally solves the teaching problem that students vary greatly in foundations and unified exercises cannot accommodate all students.

Round-the-Clock Intelligent Q&A Tutoring. Learning advanced mathematics requires a lot of after-class practice and timely Q&A. But offline teachers have limited time and energy, and students' questions often cannot be answered in time. Kunming University has developed the "KMU Smart Math Companion" system, covering all scenarios including preview before class, after-class practice and final review, giving round-the-clock intelligent learning assistance. The AI companion can provide students with answers to their questions anytime, with step-by-step explanations for problem-solving, analysis of various approaches to solve the problem, and summary of knowledge points, breaking the barriers to after-class Q&A and filling the gap of limited offline tutoring time.

5. Four Core Challenges Facing AI-Empowered Advanced Mathematics Teaching

While the integration of AI and advanced mathematics teaching has achieved phased results, there are still multiple practical challenges that cannot be ignored in the implementation process:

Obvious Shortcomings Remain in the Underlying Technology of AI. The processing capacity of complex mathematical formulas and rigorous logical reasoning capabilities of AI are still insufficient, and the compatibility of mathematical formulas in different devices and platforms needs optimization. At the same time, the problem-solving content and knowledge explanations autonomously generated by AI have a certain probability of error; all AI-generated output must be manually reviewed and verified by teachers. There is still much room for improvement in technological maturity.

Collection of Student Learning Data Raises Privacy and Data Security Risks. Various AI teaching systems require a large amount of personal learning data including students' grades, answering records and online learning behaviors. How to balance the teaching value of data with the protection of students' personal privacy, and how to establish standardized mechanisms for data collection, storage and use, are ethical and security issues that must be faced in education digitalization.

Role Transformation of Teachers Faces Digital Competence Barriers. With the help of AI, the role of teachers is changing from the single role of knowledge transmission to the role of course designer, learning guide, and thinking cultivator. This transformation needs teachers to be skilled in the diverse AI teaching tools and have digital and personalized teaching ideas. At this stage, however, a large number of college mathematics teachers are not proficient in operating AI teaching tools and lack digital teaching literacy, and it is difficult to fully unleash the teaching value of AI.

The Integration of Technology and Teaching Easily Remains at a Superficial Level. Although AI technology has shown great potential in advanced mathematics teaching, its high technical costs and uneven distribution of resources have become important factors restricting its popularization [9]. AI technology is costly, and it's essential to have significant financial resources to maintain and develop it. In economically less developed regions, universities may find these costs unaffordable, which leads to uneven application of the technology. Secondly, the level of information infrastructure construction varies greatly between schools. Some schools may lack necessary infrastructure such as smart classrooms and high-speed networks, making it difficult to fully leverage the advantages of AI technology. Furthermore, there is also an uneven distribution of high-quality teaching resources. AI teaching tools and content may not be available in some areas, further exacerbating educational inequality [10].

6. Future Prospects and Conclusion

AI's capacity to support personalized and tiered learning will continue to grow and improve as these technologies evolve and mature, and the triadic human-machine collaborative classroom teaching model will continue to mature. In the future, AI-powered advanced math teaching will be truly transformed from "knowledge transmission" to "ability empowerment".

AI-empowered advanced mathematics teaching brings three fundamental changes at the underlying level. First, the logic of teaching decisions has changed from being based on teachers' own experience, to being based on students' learning data. Secondly, the teaching model has changed from unified and standardized collective teaching to personalized and tiered teaching according to students' differences. Thirdly, the classroom relationship between teachers and students has changed from a single direction of knowledge indoctrination to a new type of classroom teaching system, which is a combination of teachers and machines and has multiple dimensions of interaction.

AI-empowered advanced mathematics teaching is a major development opportunity for education digitalization reform. But considering the imbalance of resource distribution and the cost issues concerning the use of AI technology in advanced math education, future studies should focus on finding more cost-effective and efficient solutions. For instance, through government support and cross-regional cooperation, the sharing and popularization of high-quality educational resources may be promoted, and the technological differences between regions and schools may be reduced. Developing lightweight, low-cost AI teaching tools will also help to lower the threshold for technology application, so that more education institutions can benefit from the development of AI technology. Meanwhile, there are still several practical issues, such as data security, teachers' digital literacy, and ideas for integrating technology with teaching, which require the coordinated efforts of university teachers, AI technology research and development teams, and education policy-making departments, to continuously improve the human-machine collaborative smart teaching system of advanced mathematics. In the era of artificial intelligence, the reform and innovation of advanced mathematics teaching is both a challenge and an opportunity.

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