Region - Educational Research and Reviews, 2026, Volume 8, Issue 4
DOI: 10.32629/rerr.v8i4.5341
ISSN Online: 2661-4634
ISSN Print: 2661-4626

Pathways for AI-empowered reform of Advanced Mathematics teaching in the new era

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Abstract: Advanced Mathematics is a core foundational course for majors in science and engineering as well as economics and management in higher education. Characterized by rigorous logic, abstract nature and practical applicability, it plays an important role in cultivating students' logical thinking, mathematical analytical ability, and capacity for innovative practice. Traditional Advanced Mathematics teaching has long been constrained by rigid instructional models, abstract knowledge presentation, delayed diagnosis of students' learning status, and a single-dimensional evaluation system, making it difficult to meet the new era's requirements for personalized education and precision teaching in higher education. With the rapid development of artificial intelligence, technologies such as intelligent data analysis, visualization-based teaching, personalized content recommendation, and whole-process assessment have become deeply integrated with education and teaching, thereby opening up new pathways for the reform of Advanced Mathematics teaching. Against the background of the development of higher education in the new era, this paper analyzes the advantages of AI-empowered reform in Advanced Mathematics teaching and explores implementation pathways for the deep integration of artificial intelligence with Advanced Mathematics instruction across the full teaching process, including before-class preparation, in-class teaching, and after-class consolidation, which can serve as a practical reference for colleges to carry out digital and intelligent transformation of Advanced Mathematics teaching.

Keywords: artificial intelligence; Advanced Mathematics; teaching reform; personalized teaching; whole-process education

1 Introduction

For a long time, Advanced Mathematics teaching in Chinese universities has generally followed a standardized model featuring unified lectures, identical teaching schedules and consistent assignments. Teachers mainly conduct lecture-based theoretical instruction through blackboard writing and courseware, resulting in a relatively fixed and monotonous teaching form. Under the traditional teaching model, on the one hand, abstract topics in Advanced Mathematics, such as limits, derivatives, integrals, and infinite series, are difficult to demonstrate intuitively. Students with weak foundations often find it difficult to master the core logic quickly and are therefore prone to falling behind. On the other hand, teachers struggle to accurately grasp each student's learning status, which makes it hard to meet the requirements of differentiated instruction and creates the dilemma that high-achieving students are insufficiently challenged while students with weaker foundations struggle to keep up with teaching progress. Leveraging big data analysis, intelligent interaction, dynamic monitoring, and visual presentation, artificial intelligence can precisely tackle prominent pain points in Advanced Mathematics teaching. It breaks the temporal-spatial constraints and model limitations of traditional instruction, and promotes a shift from "standardized knowledge transmission" to "precision-oriented education".

2 Advantages of AI-empowered reform in advanced mathematics teaching

2.1 Realizing differentiated instruction and personalized learning

University students come from diverse educational backgrounds, with wide disparities in their mathematical foundations, logical reasoning capabilities and learning rhythms. A unified teaching model cannot meet students' personalized learning demands, making it hard to carry out differentiated instruction effectively. Through big-data-based learning analytics systems, artificial intelligence can accurately capture core learning data such as students' prior academic foundation, learning habits, mastery level of knowledge, and weak knowledge points. Based on algorithmic modeling, it can construct personalized learning profiles and precisely identify learning differences among students at different levels.

Drawing on well-developed learning profiles, the AI system can automatically categorize students into three learning levels: the foundation-consolidation level, the capability-enhancement level, and the innovation-extension level. It can then recommend different learning content, exercise tasks, and learning resources to students at different levels. For students with weak mathematical foundations, the system recommends explanations of basic concepts, analyses of simple examples, and basic exercise training so as to consolidate their knowledge foundation. For intermediate-level students, it recommends key and difficult problem types as well as knowledge-specific differentiated exercises to boost their capacity for knowledge application. For students with sound foundations and outstanding academic capabilities, the system recommends comprehensive applied problems, mathematical modeling cases, and frontier extension materials to meet their demands for deep learning and innovative exploration.

2.2 Addressing difficulties in teaching abstract mathematical knowledge

Compared with elementary mathematics, Advanced Mathematics has a more abstract knowledge system and more rigorous logical structure. Concepts including the idea of infinite approximation in limits, the spatial geometric forms of multivariable functions, the dynamic evolution of differential equations, and the spatial operations involved in surface integrals are difficult to present intuitively through static text or simple blackboard writing. Consequently, these concepts represent prominent challenges in undergraduate mathematics instruction [1].

AI-supported visualization teaching technologies and dynamic simulation technologies can effectively address this instructional difficulty. Through three-dimensional modeling, dynamic demonstration, and process simulation, abstract mathematical concepts, complex formula derivations, and obscure spatial geometric relationships can be transformed into intuitive dynamic images. Intelligent teaching platforms can dynamically demonstrate the process through which sequences approach their limits, the continuity and discontinuity of function graphs, and variations in regions of surface integrals, thereby concretizing and visualizing abstract mathematical logic. By observing dynamic changes intuitively, students can understand the core principles behind mathematical knowledge, and break away from rote mechanical exercises. The AI system reduces their difficulty in learning Advanced Mathematics and helps improve their learning motivation and conceptual comprehension.

2.3 Improving the whole-process teaching evaluation system

Teaching evaluation is an important basis for measuring teaching effectiveness and improving teaching models. The traditional evaluation system for Advanced Mathematics teaching has obvious deficiencies: in most cases, the final written examination score is used as the sole evaluation criterion. This is a form of summative assessment that overlooks students' learning process, learning attitude, progress, and cognitive development. As a result, evaluation outcomes are one-sided and delayed; they neither comprehensively reflect students' real learning levels nor precisely identify weaknesses in the teaching process.

By establishing a comprehensive intelligent teaching evaluation system, artificial intelligence can transform evaluation from summative assessment into process-oriented and comprehensive assessment. Intelligent teaching platforms can record learning data throughout the entire process, including pre-class preparation, classroom interaction, exercise completion, after-class review, error correction, and extended learning. With big data algorithms, they can quantitatively analyze students' learning attitude, knowledge mastery, problem-solving ability, level of thinking, and academic progress, thereby generating dynamic learning evaluation reports [2].

2.4 Improving teaching efficiency and students' autonomous learning ability

In traditional Advanced Mathematics teaching, teachers have to devote substantial time to grading assignments, collecting and analyzing students' error records, summarizing students' learning performance, and organizing teaching materials. Such repetitive work occupies much of their teaching time, making it difficult for them to devote sufficient energy to core teaching tasks such as instructional design, explanation of key and difficult points, and personalized tutoring. As a result, teaching efficiency is low. Moreover, the time and space available for classroom teaching are limited, and students who encounter difficult problems after class often cannot receive timely answers. Over time, this readily gives rise to knowledge loopholes and significantly undermines learning performance.

Functions such as AI-powered question answering, automatic grading, and resource integration can efficiently replace repetitive teaching work. The system can automatically grade objective questions, intelligently analyze subjective questions, quickly identify high-frequency wrong answers and common knowledge gaps in the class, and automatically generate learning analytics reports. This reduces teachers' workload and enables them to devote more energy to instructional design, precise question answering, and the cultivation of students' thinking ability, thereby effectively improving overall teaching efficiency.

3 Implementation pathways for AI-empowered reform in Advanced Mathematics teaching

3.1 Before class: AI-driven learning performance prediction and personalized preview recommendation

Pre-class preparation is an important link in improving classroom teaching efficiency and consolidating students' learning foundation. Traditional pre-class preparation often suffers from formalism, lack of specificity, and absence of feedback. Teachers usually assign uniform preview tasks to all students, which cannot accommodate discrepancies in students' prior knowledge foundations. As a result, most students' preview work remains superficial and fails to achieve the intended effect. By relying on artificial intelligence, an intelligent pre-class preparation system can be established to realize precise prediction of students' learning performance and personalized recommendation of preview materials.

Prior to delivering a new lesson, the intelligent teaching platform retrieves students' historical learning data, examination results, and error records. Combined with the difficulty level of the knowledge points in the lesson, the platform adopts big data algorithms to predict the learning performance of the whole class, accurately identifying the basic knowledge points that students have already mastered, existing knowledge gaps, and potential difficulties they may encounter in learning the new lesson. Based on the prediction results, the system generates a customized preview plan for each student, thus realizing personalized preview recommendation on a "one student, one plan" basis. For students with weak foundations, the system focuses on recommending micro-lectures on basic concepts, courseware for knowledge-point organization, and basic preview questions, together with review resources for prerequisite knowledge, so as to help them make up for deficiencies in prerequisite knowledge and reduce the difficulty of learning the new lesson. For students with better foundations, it recommends learning materials for key and difficult points, exploratory thinking questions, and interrelated knowledge case studies, thereby guiding students to organize knowledge logic in advance and carry out deep learning [3].

After students complete the preview tasks, the system automatically collects preview data, records completion status, wrong answers, and questions about knowledge points, and generates a class-wide preview learning report that is synchronized with the instructor in real time. Based on these preview data, the teacher can accurately grasp the overall preview performance of the whole class, common misconceptions, and individual weaknesses, so as to adjust classroom instructional design in a targeted manner.

3.2 During class: intelligent interaction and visualization-supported precision teaching

The classroom is the primary setting for Advanced Mathematics teaching. Traditional classroom teaching is dominated by one-way knowledge transmission from teachers to students, with limited teacher-student interaction, monotonous teaching forms, unclear explanation of key and difficult points, low student participation, difficulty in maintaining attention, and low classroom efficiency. Through artificial intelligence, an intelligent classroom teaching model can be reconstructed to realize intelligent interaction, visualization-supported teaching, and precision instruction, thereby revitalizing the classroom.

On the one hand, AI visualization teaching technology can help overcome instructional difficulties. Leveraging the dynamic simulation and three-dimensional visualization functions of intelligent teaching platforms, teachers can transform abstract knowledge points such as limits, differentials, multiple integrals, and space vectors into intuitive dynamic images. This enables students to perceive the formation process of mathematical knowledge directly, deeply understand its core logic, and break through the cognitive barriers of traditional instruction.

On the other hand, an intelligent interactive classroom can be established to monitor students' learning status in real time. In classroom teaching, teachers can leverage intelligent platforms to distribute in-class questions, real-time exercises, and classroom quizzes. Students submit responses via digital terminals, and the system instantly conducts data aggregation, accuracy analysis, and error categorization, thereby presenting the real-time learning status of all students in class. Common incorrect answers and prevalent misconceptions that emerge in class can be collectively interpreted and resolved as core teaching priorities; individual learning difficulties of specific students can be archived as learning data, creating room for precise after-class tutoring [4].

3.3 After class: AI-assisted question answering, error correction, and layered assignment design

After-class consolidation serves as a vital session for students to absorb in-class knowledge, identify and make up for knowledge gaps, and strengthen the ability to apply knowledge. Traditional after-class teaching often suffers from homogeneous assignments, delayed question answering, unsystematic error correction, and unfocused review, making it difficult to realize precise after-class education. Artificial intelligence can support an intelligent after-class consolidation system that integrates layered assignments, intelligent question answering, precise error correction, and long-term review, thereby forming a closed teaching loop.

First, intelligent layered assignment design should be implemented. After classroom teaching, the intelligent platform automatically generates differentiated after-class assignments tailored to students' knowledge mastery levels, based on dynamic learning data accumulated from preview activities and classroom sessions. Students with weak foundations are assigned exercises centered on basic question types to consolidate core classroom knowledge. Intermediate-level students focus on key, difficult, and comprehensive question sets to boost their knowledge application capabilities. Outstanding students focus on extended exercises, mathematical modeling applications, and innovative problem types to cultivate innovative thinking and practical ability, thereby avoiding the inefficiency caused by homogeneous assignments.

Second, an all-time intelligent question-answering and precise error-correction system should be established. When students encounter difficult problems during after-class practice and review, they can ask questions through the intelligent platform at any time. Relying on massive question banks and knowledge-point databases, the AI question-answering system can quickly and accurately analyze the tested knowledge points, solution ideas, and error-prone points, provide step-by-step solutions, and respond to students' questions in real time, thus addressing the problem of insufficient guidance in after-class learning. At the same time, the system automatically collects students' incorrect responses after class, generates an individualized error log for each student, automatically categorizes the knowledge gaps corresponding to these errors, analyzes the root causes of errors, and recommends targeted variant exercises of identical question types. In this manner, students can conduct repetitive targeted drills, accurately rectify errors precisely, and make up for knowledge deficiencies.

4 Conclusion

The deep integration of artificial intelligence with Advanced Mathematics teaching is an inevitable trend in the digital transformation of higher education in the new era. It is also an important pathway for addressing the pain points of traditional Advanced Mathematics teaching, optimizing teaching models, and improving the quality of talent cultivation. With advantages such as personalized learning analytics, visualized teaching presentation, whole-process diversified evaluation, and full-process intelligent empowerment, artificial intelligence effectively solves many problems in traditional Advanced Mathematics teaching, including rigid teaching models, the absence of differentiated instruction, abstract knowledge explanation, a single evaluation system, and low teaching efficiency. It promotes the comprehensive transformation of Advanced Mathematics teaching from "teacher-centered, knowledge-transmission-oriented, and uniform instruction" to "student-centered, precision-oriented education, and individualized development".

Acknowledgments

This work is supported by the Shanxi Provincial Higher Education Teaching Reform and Innovation Project: Research on a Cultivation Model for Outstanding Science and Engineering Talents with "Innovation + Ideological and Political Education" as Dual Wings (No. J20240925), and Hunan Provincial Teaching Reform Research Project for Regular Undergraduate Higher Education Institutions: Research on Blended Teaching Reform of Functions of a Complex Variable from the Perspective of Curriculum-Based Ideological and Political Education (No. 202502000822).

Conflicts of interest

The author declares no conflicts of interest regarding the publication of this paper.

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