International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 9 Issue 4, Jul-Aug 2025 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Application of Artificial Intelligence in Higher Mathematics Course Teaching

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ABSTRACT

Advanced Mathematics is a crucial foundational course, and the advancement of Artificial Intelligence technology has brought new vitality to its teaching reform. This article explores the application of Artificial Intelligence across various aspects of Advanced Mathematics courses, including resource pool construction, intelligent learning process support, and intelligent evaluation. To further realize this application, specific strategies and pathways are discussed, focusing on strengthening faculty development, enhancing resource construction, and fostering student self-motivation. These measures aim to improve the quality and efficiency of Advanced Mathematics teaching.

KEYWORDS: *Artificial Intelligence; Advanced Mathematics; Application Scenarios; Strategies.*

How to cite this paper: Xiaoyan Wang "Application of Artificial Intelligence in Higher Mathematics Course Teaching" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-9 | Issue-4, August 2025, pp.1121-1127, URL: www.ijtsrd.com/papers/ijtsrd97353.pdf

IJTSRD97353

INTRODUCTION

With the rapid advancement of Artificial Intelligence (AI) technology, profound transformations are occurring across all domains of social production and daily life. The field of education is likewise experiencing unprecedented opportunities for reform. Advanced Mathematics, a foundational discipline in higher education characterized by high abstraction, rigorous logic, and broad applicability, serves as a critical cornerstone for cultivating science and engineering talents. Its teaching quality directly impacts students' subsequent professional coursework and innovative ability development [1].

In this context, AI development has infused new vitality into the reform of the Advanced Mathematics course. Thorough exploration of AI application pathways and practical value in Advanced Mathematics instruction represents not only an essential response to contemporary trends [2], but also a key measure to: innovate teaching methodologies, enhance instructional quality and efficiency, promote personalized student learning and competency development. This exploration holds significant importance for deepening the reform of higher education teaching.

Application Scenarios of Artificial Intelligence in Teaching

Artificial Intelligence has numerous application scenarios in Advanced Mathematics instruction, including intelligent resource library construction, intelligent learning support, and intelligent evaluation.

A. Intelligent Resource Library Construction

When generating an Advanced Mathematics teaching resource library, an Artificial Intelligence classifies and creates content, such as course videos, exercises, and lesson plans, while optimizing, reviewing, and updating resources. The specific processes are:

1. Course Video Generation

First, perform a deep analysis of the Advanced Mathematics textbook content. Using Natural Language Processing (NLP) technology, conduct tokenization, syntactic analysis, and semantic understanding of the text [3] to extract key knowledge points, theorem formulas, and example analyses, constructing a knowledge graph to clarify logical relationships.

Next, apply speech synthesis technology with a timbre matching Advanced Mathematics teaching style to convert knowledge points into natural speech. For animation, adopt Deep Learning-based generation algorithms to automatically create visuals such as function images and geometric figures [4]. For instance, derivative concepts can be demonstrated through tangent line animations.

Finally, use multimedia integration technology to synchronize speech and animation into high-quality videos. Employ Computer Vision (CV) technology for quality inspection, ensuring visual clarity, audio fidelity, and content accuracy.

2. Exercise Generation

Collect Advanced Mathematics exercises from textbooks, past exams, and tutoring materials. Classify them by knowledge points (Limit, Derivative, Integral) and difficulty levels (easy, medium, difficult) to build a standardized database.

Apply supervised learning algorithms to train artificial intelligence models using this database [5]. The models learn exercise structures, knowledge point distributions, and solution approaches to master generation rules. For Integral exercises, models learn method variations for different function types.

Set knowledge point and difficulty parameters to generate exercises [6]. Ensure accuracy through cross-validation with database exercises and logical verification via mathematical inference engines.

3. Lesson Plan Generation

Collect student data (class performance, homework, test scores) through learning analysis systems. Use data mining to analyze knowledge mastery, learning habits, and difficulties, constructing student profiles.

Determine teaching objectives based on the syllabus. Combining with profiles, artificial intelligence models select appropriate content, methods, and pacing.

For example, for knowledge points that students generally have a poor grasp of, more time for Solution and practice is arranged in the lesson plan.

Integrate teaching resources (e.g., recommending videos/exercises for specific knowledge points). Enable dynamic adjustments based on real-time learning feedback.

4. Resource Optimization, Review, and Update

Artificial Intelligence will conduct multi-dimensional evaluations of the generated teaching resources, such as the viewing duration of course videos, the accuracy rate of exercises, and the effectiveness of lesson plans, and optimize the resources based on the evaluation results.

Arrange professional Advanced Mathematics teachers to review the generated resources to ensure the scientificity and accuracy of the content.

For the problems found in the audit, feedback is given to the artificial intelligence model to allow it to correct and learn.

Combining teaching feedback and the dynamics of subject development, artificial intelligence uses web crawler technology to acquire the latest academic achievements and teaching methods, and automatically updates the content in the resource library to ensure the timeliness and advancement of the resources.

B. Intelligent Learning Process Support

Artificial Intelligence facilitates intelligent learning for Advanced Mathematics, which requires realization through multifaceted collaboration, tailored to both student and subject characteristics. The specific processes and methods are as follows:

1. Accurate Analysis of Learning Needs

Collect student data (admission tests, math scores, study time) and preferences (learning goals, resource preferences) via questionnaires.

Using Machine Learning Algorithm to analyze data and construct student profiles that include knowledge weak points, learning ability levels, and learning styles. For example, if the data shows that a student's accuracy in the Differential Equation section is less than 40%, they will be marked as a weak object for that knowledge point.

2. Personalized Learning Paths

Generate paths using Advanced Mathematics knowledge graphs (e.g., Derivative-Integral inverse relationships) and student profiles.

Foundational students start with functions and limits before progressing to derivatives/integrals; advanced learners tackle multivariate function calculus directly. Paths dynamically adjust, accelerating progress when knowledge point accuracy exceeds 80%.

3. Intelligent Tutoring and Interactive Learning

During exercises, Natural Language Processing (NLP) analyzes solution steps [7]. Errors trigger real-time targeted explanations (e.g., animated examples for indefinite integral substitution errors).

An intelligent Question Answering (QA) System answers queries using semantic matching [8], responding via plain language or graphical demonstrations (e.g., 3D models for spatial surfaces).

4. Dynamic Evaluation and Feedback of Learning Effectiveness

A multi-dimensional evaluation system is adopted, including quantitative assessments (chapter quizzes, comprehensive exams), as well as qualitative assessments (learning focus, innovative approaches).

Generate reports highlighting strengths (calculation accuracy) and weaknesses (proof logic gaps), recommending remedies (e.g., proof-thinking courses). Feed results back to path planning for optimization.

5. Adaptive Learning Resource Adaptation

Learning resources are intelligently matched to the learning path and real-time progress. When explaining the Mean Value Theorem, animation videos are provided for visual learners, and podcasts explaining the solution are provided for auditory learners.

Adjust resource difficulty based on performance: three consecutive correct medium exercises trigger high-difficulty variants; increased errors revert to basic questions—maintaining the "zone of proximal development."

C. Intelligent Evaluation

Artificial Intelligence conducts multi-dimensional Advanced Mathematics evaluations, combining process and outcome data:

1. Multi-Dimensional Evaluation Framework. Define core dimensions:

First, clarify the core dimensions of evaluation, including knowledge mastery (e.g., theorem application, formula calculation), thinking ability (e.g., logical Inference, abstract modeling), and learning behavior (e.g., exercise frequency, error correction speed). The Delphi method is used to invite mathematics education experts to assign weights to each dimension, for example, knowledge mastery accounts for 40%, thinking ability accounts for 35%, and learning behavior accounts for 25%, forming a scientific evaluation framework.

2. Full-Scenario Data Collection Collect real-time platform data:

Leveraging the learning platform's logging system, learning data of students is collected in real time, including: problem-solving process (time spent on each step of calculation, modification traces), video learning (pause nodes, repeatedly viewed segments), forum interaction (question quality, Solution contribution to answers), etc. Data such as offline tests and scanned copies of assignments are also integrated and converted into structured information through OCR technology.

The collected data is cleaned to remove outliers (e.g., duplicate submissions caused by misoperation) and standardized (e.g., converting scores of different question types into a percentage system), constructing a student learning dataset containing 50+ features.

3. Evaluation Model Training and Optimization

A hybrid model architecture is employed: the Decision Tree Algorithm is utilized to analyze knowledge mastery by comparing the matching degree between students' answers and standard answers, calculating the accuracy rate for each knowledge point; the LSTM Neural Network (NN) solution is used to analyze thinking ability by semantically encoding the derivation steps of proof questions to evaluate the integrity of the logical chain [9]; and the Clustering Algorithm is used to analyze learning behavior and identify groups such as "efficient learners," "procrastinating learners," and other features [10].

Train models using historical teacher-evaluated data. Adjust parameters via cross-validation (e.g., increase "Differential Equation modeling" samples if deviation >10% until accuracy >90%).

4. Dynamic Evaluation Implementation Process

After submitting an integral problem, feedback appears in 10 seconds (e.g., "Substitution method correct but missing constant term. 'Indefinite Integral properties' mastery: B+").

Stage-based (e.g., mid-term): Weighted scores from chapter tests (knowledge), proof question steps (thinking), and practice duration attainment (behavior) generate comprehensive grades (A-F) with radar chart visualizations.

5. Application and Iteration of Evaluation Results

Transform evaluation results into personalized feedback: push specialized micro-courses for weak knowledge points, recommend "Multiple Solution for One Question" training questions for thinking shortcomings, and send learning plan reminders for behavioral problems. At the same time, generate learning reports for teachers, marking common class vulnerabilities (e.g., "Lagrange's Mean Value Theorem application error rate 72%").

Update models monthly: incorporate manual teacher reviews (20% random samples) to correct deviations, and add new question types/knowledge points (e.g., mathematical modeling criteria).

Strategies for Implementing Artificial Intelligence in Advanced Mathematics Applications

A. Strengthening Faculty Development

1. Conduct Systematic Artificial Intelligence Skills Training

Design a tiered training system for Advanced Mathematics teachers: The foundational tier focuses on the operation of AI tools, such as teaching data analysis platforms and intelligent question bank systems. Through practical courses, teachers will master methods for extracting and interpreting student learning data, such as using system-generated class integral knowledge point mastery heatmaps to quickly identify weak areas in teaching. The advanced tier delves into the principles of AI in teaching, offering courses such as the application of Machine Learning (ML) in mathematics education and the logical architecture of intelligent tutoring systems. Experts in the field of AI education will be invited to teach, combining AI with Advanced Mathematics case studies to help teachers understand the evaluation mechanism of intelligent evaluation models for the logical chains in proof problems.

Establish a training and certification mechanism, incorporating AI skills into teacher assessment indicators. Teachers will be required to participate in advanced order training regularly to ensure they keep up with the iterative application of AI technology in mathematics education. Meanwhile, build an online training resource library, including recorded courses, operation manuals, and frequently asked solution questions and answers, to facilitate teachers' self-directed learning at any time.

2. Support teacher-led AI teaching model innovation

Encourage teachers to explore AI-integrated teaching models, leveraging the unique aspects of Advanced Mathematics instruction, and provide them with resource support. For instance, assist teachers in utilizing Natural Language Processing (NLP) technology to create an "Advanced Mathematics Intelligent Q&A Teaching Assistant." This can be achieved by aggregating students' frequently asked questions, such as "What is the difference between definite and indefinite integrals?" to train the model, thereby enhancing classroom engagement. Additionally, equip teachers with AI instructional design tools to convert conventional lesson plans into dynamic ones suitable for intelligent learning platforms, enabling the capability to automatically adjust the complexity of example questions in response to students' real-time answer data.

Establish an AI Teaching Innovation Fund to back teachers in conducting pilot projects (e.g., the "AI-based Micro-Integral Hierarchical Teaching Experiment"). Offer technical team support to participating teachers to aid in analyzing experimental data and distilling scalable teaching models. Regularly organize on-campus AI teaching achievement exhibitions to foster the exchange of experiences among educators.

3. Construct AI + Advanced Mathematics Teaching-Research Collaboration Mechanism

Form interdisciplinary teaching and research teams comprising Advanced Mathematics teachers, AI technicians, and educational psychology experts to discuss the application scenarios of AI in Advanced Mathematics teaching. For instance, regarding the intelligent exercise generation system, teachers propose the need to "include practical scenario cases of Differential Equation application problems," and AI technicians subsequently optimize the algorithm accordingly. Meanwhile, educational psychology experts suggest establishing an order-based, tiered reward mechanism from the perspective of enhancing learning motivation.

Establish a normalized seminar system, holding monthly teaching and research meetings focused on practical problems in AI applications. Address issues such as "managing discrepancies between intelligent evaluation results and teachers' subjective scores" and "utilizing AI data to refine the teaching steps of theorem derivation," to develop actionable solutions and integrate them into teaching guidelines. Collaborate with university AI laboratories to build joint teaching and research bases, offering teachers opportunities to engage with cutting-edge AI technologies and participate in the iterative development of intelligent higher mathematics teaching systems.

4. Enhance Teacher Reflective Practice in AI Instruction

Cultivate critical thinking among teachers in AI-assisted instruction, guiding them to recognize the limitations of AI tools. For instance, when employing intelligent evaluation systems, teachers should leverage their own teaching expertise to conduct secondary reviews of the system's assessments, such as identifying "incomplete logic in proof questions," to prevent misjudgments that may arise from the Model's inadequate recognition of mathematical intuitive inference.

Through case-based instruction, teachers can master the collaborative approach of "manual review+Model optimization." For example, upon discovering an evaluation bias in a particular type of Integral substitution error, specific instances can be communicated to the technical team to adjust the Model parameters accordingly.

Organize AI teaching reflection workshops, where teachers are required to document AI tool usage logs, encompassing aspects like the "suitability of intelligently recommended exercises" and "student feedback on AI Q&A," and so on. Conduct regular collective reviews to distill an "AI-assisted Advanced Mathematics teaching decision-making framework," delineating which instructional segments are best led by AI (e.g., large-scale learning analysis) and which should be guided by teachers (e.g., detailed explanations of mathematical concepts and problem-solving).

B. Strengthen Resource Construction

1. Construct a Multi-Dimensional Digital Resource Library for Advanced Mathematics

Build a three-dimensional resource system covering "knowledge points - exercises - cases - tools."

In terms of knowledge resources, we will meticulously break down the core content of Advanced Mathematics (e.g., Limit definitions and Integral theorems), creating multimedia resource packages that include textual Solution analysis, dynamic graphics (e.g., 3D rotation demonstrations of Function images), and micro-videos (5-10 minute theorem derivation lectures). Each resource package will be labeled with the knowledge point's difficulty, associated test points, and adapted learning Order stages.

We will build a dynamically updated exercise resource library, categorized in three dimensions: "knowledge point + question type + difficulty," and include basic questions, comprehensive questions, and innovative application questions (e.g., Differential Equation questions combined with physical scenarios). Each exercise will be accompanied by a multi-step Solution analysis, common error annotations, and a similar question recommendation Label.

Meanwhile, real-time collected student answer data is introduced, and high-frequency incorrect questions and typical Solution question paths are supplemented through AI analysis to form a closed loop of "generation-application-feedback-iteration".

Develop a resource set of advanced mathematics visualization tools, including Function Image Generation tools, geometric figure simulators (e.g., spatial surface cutting demonstrations), numerical calculation verification tools, etc., to support students' independent operation and exploration. All tools are connected to a unified interface to facilitate AI system calls for auxiliary teaching.

2. Build an intelligent resource generation and optimization system

Implement a Deep Learning-based resource generator. For exercises, train a Neural Network (NN) Model with mathematical logic Inference capabilities. Input knowledge points (e.g., "Double Integral calculation"), difficulty parameters, and scenario requirements (e.g., "engineering Volume calculation"), and the model can automatically generate question stems, options (e.g., multiple-choice questions), Solution question steps, and answers, and verify the accuracy of the results through a symbolic calculation engine.

Create intelligent multimedia authoring tools: Teachers input theorem explanations, and the system automatically matches animations (e.g., Definite Integrals' "partition–approximation–summation–Limit" process) to generate micro-lectures using speech synthesis. Content rhythm and presentation formats remain teacher-adjustable.

Establish a resource quality optimization mechanism that employs AI to analyze resource usage data, including the accuracy distribution of exercises (flagged as abnormally difficult if accuracy falls below 30%) and the average viewing duration of videos (indicating insufficient content appeal if shorter than anticipated). The system should automatically provide optimization suggestions to the resource production team and update resource quality standards quarterly, in collaboration with subject matter expert reviews.

3. Developing a Cross-Platform Resource Sharing and Adaptation System

Launch a cloud-based Advanced Mathematics resource hub integrating content from universities and publishers. Standardized data formats (e.g., XML Label for knowledge points) enable cross-platform interoperability. For instance, the "Fourier Series Interactive Courseware" developed by a university can be seamlessly embedded into the course modules of other institutions' intelligent teaching systems.

Develop a resource adaptation engine that automatically adjusts the resource presentation format according to different application scenarios (e.g., classroom teaching, self-study preview, and pre-exam review): highlighting example Solution explanations and interactive exercises during classroom teaching, focusing on concept introduction and basic demonstrations during self-study preview, and integrating high-frequency test point lectures and mock test papers during pre-exam review.

Implement contribution incentives: Teachers earn credit (based on user ratings/utilization) for sharing original resources (e.g., AI-enhanced exercises, adapted cases), redeemable for technical support or teaching rewards. A review committee ensures scientific validity, fostering a "co-build, co-share, win-win" ecosystem. Simultaneously, establish a resource review committee to ensure the scientific accuracy and applicability of shared resources.

C. Enhancing Students' Self-Motivation

Artificial Intelligence (AI) enhances students' self-motivation in advanced mathematics courses through personalized guidance, incentive mechanisms, and learning outcome visualization. The specific methodologies are as follows:

1. Constructing a Personalized Learning Goal and Path Guidance System

AI analyzes students' initial learning status (e.g., entrance test scores and learning preference questionnaires) to generate "Ordered Ladder-style Learning Goals" for each student. For those with weaker foundations, goals may include "mastering the definition and basic calculations of Limit within one week," followed by "applying L'Hôpital's Rule to solve indeterminate forms." For advanced learners, goals could involve "completing applied extension exercises on the Definite Integral in physics within three weeks."

The intelligent system decomposes major goals into daily achievable tasks (e.g., "Master the derivation of 2 Integral formulas + complete 5 corresponding exercises today") and proactively delivers task lists upon platform login. Simultaneously, leveraging knowledge graphs, the system highlights goal relevance. For example, after completing "Geometric Meaning of Derivative," a notification states: "This underpins subsequent topics on tangent equations and Function monotonicity. Achieving this week's goal unlocks the Mean Value Theorem animation course," reinforcing learning purpose.

2. Designing Dynamic Incentives and Interactive Feedback Mechanisms

Incorporating gamified elements, the system provides real-time feedback on learning behaviors.

Examples include awarding a "Persistence Badge" for three consecutive days of task completion or unlocking the "Problem-Solving Expert" title for a 50% improvement in solving accuracy. Virtual rewards may be redeemed for privileges (e.g., priority access to difficult solving analysis videos or high-difficulty challenges).

The "Intelligent Learning Companion" feature simulates peer interaction using conversational prompts. When answers are incorrect, it queries: "How would you set variables here using substitution?" During learning blocks, it encourages: "Peers at your level mastered this last week. View their problem-solving approach?"

Meanwhile, adjust the interaction style based on the student's personality profile, offering more encouragement to introverted students and setting more competitive goals for those who are competitive.

3. Visualizing Learning Outcomes and Attribution Analysis

The intelligent system automatically records students' learning data and generates a "Personal Growth Dashboard," using dynamic charts to display the progress of knowledge point mastery (e.g., using a progress bar to show that 70% of the "Points" module has been mastered), changes in Solution speed (e.g., "Compared to last week, the time for Differential Equation Solution has been reduced by 20%"), and the distribution of error types (e.g., "30% of errors are concentrated in the sign processing of integration by parts").

Upon achieving goals, an "Achievement Report" details grade improvements and progress drivers: "Repeated viewing of Definite Integral animations raised your 'Area Calculation' Solving accuracy from 60% to 90%. Maintain this visual learning strategy!" For setbacks, it offers constructive analysis: "Derivative errors in abstract Functions suggest consolidating methods via concrete examples (e.g., differentiating $f(x)=x^2+1$). Three foundational exercises have been recommended."

4. Supporting Self-Directed Exploration and Creative Learning

The "Advanced Mathematics Exploration Laboratory" module enables students to self-set parameters (e.g., coefficients "a", "b", "c" in $f(x)=ax^2+bx+c$). The system renders real-time Function graphs, Derivative curves, or Integral results, prompting students to discover mathematical patterns through parameter adjustments (e.g., altering power Function exponents to derive differentiation rules).

"Open-ended Project" tasks (e.g., "Calculating irregular container volumes using Definite Integral") provide measurement tools, knowledge links, and case studies—without standard answers—guiding collaborative problem-solving. Post-completion, students upload solution approaches to an "Online Achievement Exhibition," where peers vote for the "Best Creative Solution," fostering autonomy and initiative.

Summaries

Through analysis of Artificial Intelligence application scenarios in Advanced Mathematics instruction, this technology demonstrates potential to enhance teaching resources, increase instructional efficiency, and address personalized learning needs. However, realizing its full application requires solutions to challenges, including teacher AI proficiency, institutional resource allocation, and student self-motivation cultivation. Ultimately, while Artificial Intelligence provides innovative pathways for Advanced Mathematics education reform, its effective implementation demands collaborative efforts and ongoing exploration across stakeholders.

Acknowledgment

We acknowledge the support from the teaching project of Beijing Wuzi University entitled "Research on the Application of Generative Artificial Intelligence in Higher Mathematics Teaching" (Project No.: 2024jgxm24837) and the Beijing Digital Education Research Project entitled "Research on Detection and Analysis of Students' Classroom Behavior Based on Deep Learning" (Project No.: BDEC2024QN068).

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