

“Teacher-Student-Machine” Ternary Synergy: A Conceptual Framework for AI-Empowered Classroom Reform in Numerical Analysis Courses

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Abstract

The integration of artificial intelligence into higher education has become a strategic priority worldwide, with China’s Ministry of Education launching the National Digital Education Strategic Action 2.0 in 2025. Numerical Analysis, as a core course for Information and Computing Science majors, faces persistent challenges: highly abstract algorithms impose heavy cognitive loads, uni-directional classroom interaction limits personalization, and students struggle to bridge the gap from understanding algorithms to applying them effectively. This paper proposes a conceptual “Teacher-Student-Machine” ternary synergy framework for AI-empowered classroom reform in Numerical Analysis courses. The framework encompasses four interconnected dimensions: knowledge graph-based intelligent curriculum restructuring, ternary synergy teaching model construction, virtual-real integrated smart learning environment development, and multidimensional intelligent assessment systems. For each dimension, the paper specifies data inputs, AI outputs, teacher decision points, and the theoretical grounding that links proposed activities to intended learner behaviors. A governance subsection addresses student-data protection, AI error handling, academic integrity, and human review of consequential assessment decisions. This paper presents a conceptual implementation proposal rather than evaluated empirical results; the anticipated outcomes and planned indicators are intended to guide subsequent design-based research. The framework aims to provide a replicable model for AI-empowered foundational STEM course reform.

Keywords

Numerical Analysis, AI-Empowered Education, Ternary Synergy, Conceptual

1. Introduction

The integration of artificial intelligence into higher education has become a strategic priority worldwide. In 2025, China's Ministry of Education launched the National Digital Education Strategic Action 2.0, positioning intelligence as a core strategic direction and deepening the comprehensive application of AI across all educational domains (Ministry of Education of the People's Republic of China, 2025a). The Ministry of Education, together with eight other departments, issued the "Opinions on Accelerating the Digitalization of Education" (Jiao Ban [2025] No. 3), which explicitly calls for improving knowledge graphs, constructing competency graphs, deepening the application of large educational models, promoting the intelligent upgrading of curriculum systems, textbook systems, and teaching systems, and integrating AI technology throughout all elements and processes of teaching and learning (Ministry of Education of the People's Republic of China et al., 2025c). At the provincial level, the Shandong Provincial Department of Education, together with nine other departments, issued the "Shandong Province 'AI+ Education' Implementation Plan" (Lu Jiao Shu Zi [2025] No. 2), which clearly proposes that after 3 - 5 years of effort, an integrated "cloud-network-edge-device" digital infrastructure will be basically established, AI technology will be deeply integrated into the entire educational process, and smart classrooms and other new educational scenarios will accelerate their emergence (Shandong Provincial Department of Education et al., 2025a).

Numerical Analysis, as a core course for Information and Computing Science majors, plays a vital role in cultivating students' scientific computing capabilities and algorithmic thinking. The course covers essential content including error analysis, interpolation methods, numerical integration, nonlinear equation solving, and numerical methods for ordinary differential equations. However, traditional instruction faces three persistent challenges. First, the course is highly theoretical and algorithmically abstract, imposing heavy cognitive loads on students. Concepts such as convergence analysis, error propagation, and stability require substantial mathematical maturity that many students lack, leading to disengagement and superficial learning. Second, traditional classrooms operate on a unidirectional "teacher lectures - students practice" model, lacking the capability for precision teaching based on real-time learning analytics or personalized learning path recommendations. Third, there exists a significant gap between algorithmic understanding and practical application—students struggle to bridge the gap from "knowing algorithms" to "using algorithms" effectively in real-world contexts.

This paper proposes a conceptual "Teacher-Student-Machine" ternary synergy framework for AI-empowered classroom reform in Numerical Analysis courses, addressing these challenges through four interconnected dimensions: knowledge

graph-based intelligent curriculum restructuring, ternary synergy teaching model construction, virtual-real integrated smart learning environment development, and multidimensional intelligent assessment systems. For each dimension, this paper specifies data inputs, AI outputs, teacher decision points, and theoretical grounding. A governance subsection addresses ethical and practical considerations. It should be emphasized that this paper presents a conceptual implementation proposal rather than evaluated empirical results. The anticipated outcomes and planned indicators are intended to guide subsequent design-based research.

2. Literature Review

2.1. AI-Empowered Education Policy and Practice

The policy landscape for AI in education has evolved rapidly. In 2025, the Ministry of Education launched the National Digital Education Strategic Action 2.0, positioning intelligence as a strategic direction and achieving significant progress in AI education application (Ministry of Education of the People's Republic of China, 2025a). The Ministry issued multiple normative documents including the AI General Education Guidelines for Primary and Secondary Schools (2025 Edition) and the Guidelines for the Use of Generative AI by Primary and Secondary School Students (2025 Edition), providing institutional frameworks for scientific AI application across all educational levels (Ministry of Education of the People's Republic of China, 2025b). The Opinions on Accelerating the Digitalization of Education further emphasized improving knowledge graphs, constructing competency graphs, and deepening the integration of large educational models (Ministry of Education of the People's Republic of China et al., 2025c).

At the provincial level, Shandong Province has taken proactive steps. The Shandong Province "AI+ Education" Implementation Plan outlines comprehensive goals including the establishment of an integrated "cloud-network-edge-device" digital infrastructure, deep integration of AI throughout educational processes, and accelerated emergence of smart classrooms and other new educational scenarios (Shandong Provincial Department of Education et al., 2025a). An official interpretation document further clarified the plan's implementation pathway and expected outcomes (Shandong Provincial Department of Education, 2025b). These policies provide strong institutional support for classroom-level AI integration.

2.2. "Teacher-Student-Machine" Ternary Synergy in Classroom Instruction

The concept of ternary synergy represents a paradigm shift in classroom dynamics. Traditional classrooms operate on a binary "teacher-student" interaction model. The introduction of AI as a third element transforms this into a "Teacher-Student-Machine" ternary ecosystem. Research has documented that in the digital age, classroom ecosystems are restructuring from traditional teacher-student interaction models toward "Teacher-Student-Machine" ternary interaction patterns,

with AI intervention serving as a new ecological factor that triggers classroom resource reallocation and ecological niche shifts (Piao & Huang, 2025).

The ternary synergy model has been implemented across various institutional contexts. Zhang (2025) proposed a “Teacher-Student-Machine” ternary interactive teaching model for Numerical Analysis course design, transcending the “technology-as-tool” perspective to construct a generative AI-driven instructional model grounded in constructivist theory. Tongji University has demonstrated “teacher-agent-student” ternary synergy classrooms where generative AI core agents serve as “capability enhancers” and “thinking accelerators,” with classroom design following a “problem introduction - solution presentation - cross-group integration - teacher-student co-creation” learning logic (Tongji University, 2025). Training programs at multiple universities have systematically interpreted the “Teacher-Student-Machine” ternary synergy teaching model, clarifying AI integration logic through smart course construction cases and multidimensional evaluation system reconstruction (Liaocheng University Dongchang College, 2026; Dalian University of Technology, 2026). Xu et al. (2026) further explored the ternary collaborative teaching model in programming courses, validating its effectiveness in addressing the conflict between large-class instruction and personalized learning needs. These implementations provide valuable reference points for Numerical Analysis course reform.

2.3. AI Integration in Numerical Analysis Education

Recent research has examined AI integration in Numerical Analysis education from multiple perspectives. Studies on generative AI-assisted numerical iteration method teaching have demonstrated that AI technologies significantly enhance students’ understanding of mathematical principles and programming implementation capabilities (Xu & Zhang, 2025). A “Teacher-Student-Machine” ternary interaction teaching model for Numerical Analysis course design has been proposed, transcending “technology tool” perspectives to construct a generative AI-driven instructional model grounded in constructivist theory (Zhang, 2025).

Broader reform efforts have constructed comprehensive “content restructuring, model innovation, and evaluation reform” frameworks for Numerical Analysis instruction in the AI context. Zhang et al. (2025) established an AI-empowered curriculum reform framework through the reconstruction of a two-tier progressive content system combining “classical foundations with modern frontiers,” the development of intelligent personalized teaching platforms, and the implementation of deep industry-academia integration mechanisms, forming an innovative three-dimensional teaching model that integrates “theoretical foundations - algorithmic implementation - engineering applications.” Research has explored the feasibility of integrating AI technologies into Numerical Analysis courses from multiple dimensions, analyzing how AI can enrich teaching content, improve instructional methods, and promote comprehensive student development (Zhang, 2024). Under the AI and big data-driven environment, institutions have identified

the necessity of curriculum reform for Numerical Analysis and proposed corresponding reform pathways (Zhou & Ning, 2026). OBE-based practical teaching reforms in Numerical Analysis have demonstrated the effectiveness of modular instruction, inquiry-based learning, and project-case-based teaching models (Yin et al., 2025).

Despite these developments, the literature lacks an integrated framework that simultaneously addresses curriculum content restructuring, ternary synergy teaching model construction, smart learning environment development, and multidimensional intelligent assessment for Numerical Analysis courses. Existing studies tend to focus on isolated dimensions—either AI integration strategies, teaching model innovation, or evaluation system reform—without synthesizing these into a coherent pedagogical framework. This paper aims to fill that gap by proposing a conceptual framework that specifies data flows, theoretical mappings, and governance mechanisms.

3. A Framework for AI-Empowered Classroom Reform

3.1. Theoretical Foundation

The proposed framework is grounded in three educational theories. To ensure that each theory operationalizes into concrete instructional activities, **Table 1** maps each theory to specific framework components, instructional activities, and intended learner behaviors.

Table 1. Theory-to-activity mapping.

Educational theory	Framework component	Instructional activity	Intended learner behavior
Outcome-based education (OBE)	Six-module chapter structure; competency assessment	Students complete algorithm design projects aligned with predefined capability standards	Students demonstrate mastery of defined learning outcomes through project deliverables
Constructivist learning theory	Problem-driven sequence; AI extension module	Students construct knowledge by solving real-world problems and building on prior understanding	Students actively integrate new algorithmic concepts with existing knowledge structures
Human-machine collaborative learning	Ternary synergy model; AI-assisted practice	Students collaborate with AI agents for algorithm derivation, code debugging, and feedback	Students treat AI as a cognitive partner, using it to amplify rather than replace their own thinking

3.2. Knowledge Graph-Based Intelligent Curriculum Restructuring

Based on the “high-level, innovative, and challenging” requirements, the Numerical Analysis curriculum is restructured in a two-tier progression: “classical foundations - modern frontiers.” Classical content including error analysis, interpolation methods, numerical integration, nonlinear equation solving, and ODE numerical methods is retained while integrating frontier content including machine

learning foundations and numerical optimization methods in deep learning (Zhang et al., 2025).

A multidimensional knowledge graph is constructed on the Zhihuishu platform, organizing course knowledge points across four levels: “foundational concepts - algorithm principles - code implementation - engineering applications.” This knowledge graph enables attribute marking, resource association, and problem graph configuration, transforming abstract theories into visual dynamic knowledge networks. The system achieves integration of “knowledge graph, competency graph, and quality graph,” creating a “growable knowledge system” (Ministry of Education of the People’s Republic of China et al., 2025c).

3.3. “Teacher-Student-Machine” Ternary Synergy Teaching Model

The ternary synergy model operates across three phases. For each phase, Table 2 specifies the data inputs, AI outputs, and teacher decision points.

Table 2. Data inputs, AI outputs, and teacher decision points.

Phase	Data inputs	AI outputs	Teacher decision points
Pre-class	Student preview quiz responses; prior performance records; time-on-task data	Learning analytics reports; knowledge gap identification; recommended preview materials	Adjust lesson focus based on identified class-wide weaknesses; assign differentiated pre-class tasks
In-class	Real-time quiz responses; interaction frequency; code submission logs; danmaku questions	Instant feedback on quiz results; flagged misconceptions; suggested discussion prompts	Decide whether to pause for clarification; select student work for group discussion; adjust pacing
Post-class	Homework submissions; discussion forum activity; project progress; AI debugging logs	Automated grading results; personalized diagnostic reports; recommended practice problems	Review AI-flagged anomalies; moderate assessment decisions; provide targeted interventions

Pre-class. AI learning analytics systems automatically generate learning analytics reports based on student preview data, assisting teachers in precision lesson design. AI-generated preview materials and visual animations help students grasp foundational concepts before class (Xu & Zhang, 2025).

In-class. The Rain Classroom AI platform and similar tools enable real-time interaction, in-class quizzes, and intelligent Q&A. AI agents assist instruction, with students completing algorithm derivation, code debugging, and other tasks through smart devices, achieving 100% human-machine interaction coverage. Classroom design follows the “problem introduction - solution presentation - cross-group integration - teacher-student co-creation” learning logic (Tongji University, 2025).

Post-class. AI-powered automated homework grading systems provide imme-

diate feedback. Based on student learning behavior data, personalized diagnostic reports identify knowledge weaknesses, facilitating targeted instruction. Generative AI accompanies students throughout the learning process, implementing proactive pre-class preview, ternary in-class interaction, and innovative post-class practice teaching strategies. This model transforms generative AI from a “tool” into a new classroom element, evolving the traditional “teacher-student” binary classroom into a “Teacher-Student-Machine” ternary classroom where AI functions as a “capability enhancer” and “thinking accelerator” (Zhang, 2025; Tongji University, 2025).

3.4. Virtual-Real Integrated Smart Learning Environment

Leveraging university smart classrooms and online teaching platforms, a virtual-real integrated teaching space is established. In theoretical instruction, virtual simulation technologies visually demonstrate abstract concepts including algorithm convergence processes, error propagation, and iteration paths. In practical instruction, interactive environments such as Jupyter Notebook enable “what-you-see-is-what-you-get” algorithm programming practice.

A blended teaching model combining “online self-study + offline seminars + project training” is adopted. The online component provides access to digital resources, video lectures, and interactive exercises. The offline seminar component offers opportunities for discussion and clarification. The project training component enables application to open-ended problems requiring integration of multiple numerical methods and AI techniques.

3.5. Multidimensional Intelligent Assessment System

An intelligent assessment system covering “process - outcome- competency” three dimensions is constructed using AI technologies: **Table 3** specifies the indicators, scoring mechanisms, and moderation processes for each dimension.

Table 3. Assessment dimensions, indicators, and scoring mechanisms.

Dimension	Indicators	Scoring mechanism	Teacher moderation
Process (40%)	Classroom interaction frequency; online learning duration; danmaku participation; peer collaboration	Rubric-based scoring with AI-generated statistics as reference	Teacher reviews AI-generated participation summaries and adjusts for qualitative factors
Outcome (30%)	Homework accuracy; quiz scores; phased test performance	Objective scoring with AI grading; teacher reviews flagged anomalies	Teacher re-grades any items flagged by AI as uncertain; final score determined by teacher
Competency (30%)	Algorithm design quality; engineering application; innovation; teamwork	Rubric-based holistic scoring by teacher panel	Teacher panel conducts blind review of project deliverables; AI provides reference analytics only

Process Assessment. AI collects learning trajectory data, classroom interaction frequency, online learning duration, and other process indicators throughout the learning process. The system generates real-time learning analytics reports and early warning radar charts that drive students to independently identify and address knowledge gaps.

Outcome Assessment. AI-powered automated homework grading and phased testing provide immediate feedback and objective outcome evaluation.

Competency Assessment. Comprehensive evaluation through algorithm design projects, engineering application cases, and team collaboration tasks assesses higher-order competencies including problem-solving, innovation, and collaboration.

This system leverages intelligent evaluation and digital profiling technologies to achieve precision learning diagnosis, forming a new teaching paradigm of “precision diagnosis - efficient interaction - personalized improvement - formative assessment closed-loop.”

3.6. Governance and Ethical Considerations

The integration of AI into classroom instruction raises important governance and ethical considerations. This framework incorporates the following safeguards:

Student Data Protection. All student data collected through AI systems is stored on university-approved servers with access restricted to authorized personnel. Data is anonymized for research purposes, and students provide informed consent for learning analytics collection.

Informed Use of Learning Analytics. Students are informed about what data is collected, how it is used, and their rights to access and request correction of their data. Learning analytics are used for formative purposes and are not shared beyond the instructional team without explicit consent.

AI Error and Hallucination Handling. AI-generated feedback, automated grading, and content recommendations may contain errors. The framework establishes a “human-in-the-loop” review process: any AI output that affects student assessment undergoes teacher verification before being communicated to students. Students are encouraged to report suspected AI errors for teacher review.

Academic Integrity Safeguards. The use of AI tools in student work is governed by clear guidelines. For algorithm implementation tasks, students may use AI for debugging assistance but must document AI usage and demonstrate understanding through code walkthroughs. AI-generated content is not accepted as a substitute for original student work.

Human Review of Consequential Assessment Decisions. Final grades, competency assessments, and any decisions with significant academic consequences are determined by human instructors. AI provides reference analytics and preliminary scoring, but the teacher retains final authority and accountability.

4. Pedagogical Strategies for Implementation

4.1. Intelligent Curriculum Content Restructuring

Based on the “two-tier progression” approach, the Numerical Analysis curriculum is restructured to integrate classical foundations with modern frontiers. Classical numerical methods are preserved while incorporating machine learning foundations and numerical optimization methods in deep learning (Zhang et al., 2025). The knowledge graph, constructed on the Zhihuishu platform, organizes knowledge points across four interconnected levels, enabling students to navigate from foundational concepts through algorithm principles to code implementation and engineering applications. This restructuring ensures both theoretical rigor and practical relevance.

4.2. Synergy Teaching Model Implementation

The “Teacher-Student-Machine” ternary synergy model is implemented through systematic integration of AI tools across all teaching phases. Pre-class AI analytics enable precision lesson design. In-class AI platforms facilitate real-time interaction and human-machine collaboration. Post-class AI systems provide personalized feedback and diagnostic support. Classroom design follows the “problem introduction - solution presentation - cross-group integration - teacher-student co-creation” logic (Tongji University, 2025), ensuring that AI serves as an enhancer rather than a replacement for human teaching.

4.3. Algorithmic Practice System Development

An algorithmic practice system integrating Python and MWORKS with AI assistance is established, achieving “theoretical foundation - algorithm implementation - engineering application” three-in-one teaching. Students progress from understanding algorithm principles through code implementation to applying algorithms to real-world problems. AI-assisted code debugging and optimization support help students overcome programming barriers and focus on higher-order algorithmic thinking (Xu & Zhang, 2025).

4.4. Smart Learning Environment Construction

Virtual-real integrated smart learning environments are established leveraging university smart classrooms and online platforms. Virtual simulation technologies visualize abstract algorithmic concepts. Interactive programming environments enable hands-on algorithm practice. The blended teaching model combining online self-study, offline seminars, and project training supports flexible, personalized learning across time and space.

5. Expected Outcomes and Planned Indicators

Ternary Interaction Coverage. Each class session is designed to achieve no fewer than three teacher-student-machine interactions, with human-machine in-

teraction coverage projected at 100% (students using smart devices to complete tasks and receive feedback). Teachers are expected to transform from knowledge transmitters to designers and regulators of the “Teacher-Student-Machine” collaborative ecosystem.

Personalized and Collaborative Learning Innovation. Each semester is planned to produce no fewer than three innovative teaching strategy plans and implementation cases based on AI-powered personalized, inquiry-based, or collaborative learning. AI learning analytics systems are designed to generate personalized learning paths for each student, delivering differentiated learning content based on individual foundations.

Smart Environment Student Engagement. Platform student activity is projected to reach $\geq 90\%$ (weekly logins ≥ 3 times). Learning tasks completed through virtual-real integrated scenarios will account for $\geq 20\%$ of total learning tasks. Learning time will transform from “rigid synchronous time” to “flexible ubiquitous time.”

Multidimensional Intelligent Assessment. Each class session is projected to fully utilize AI technologies (learning analytics systems, automated homework grading, behavior analysis tools) for classroom teaching effect evaluation. Intelligent evaluation and digital profiling technologies is projected to enable precision diagnosis, achieving “thousand-person thousand-strategy” learning guidance.

Replicable Reform Outcomes. A complete “AI+” teaching model for Numerical Analysis tailored to Information and Computing Science characteristics will be developed, including a replicable teaching model manual/operational guide/case collection/resource package. The model is projected to be promoted to no fewer than one additional institution, providing a replicable practical template for the smart transformation of foundational mathematics courses.

6. Discussion

The proposed framework has several practical implications for educators and curriculum developers. First, it demonstrates that AI integration in foundational STEM courses can be approached through systematic, multi-dimensional design rather than piecemeal tool adoption. Second, it shows that the “Teacher-Student-Machine” ternary synergy model offers a structured way to conceptualize classroom dynamics. Third, it illustrates how knowledge graph-based curriculum restructuring can support personalized learning at scale. Fourth, it provides a replicable design template for other foundational mathematics and STEM courses considering similar digital transformation.

7. Conclusion

This paper has proposed a conceptual “Teacher-Student-Machine” ternary synergy framework for AI-empowered classroom reform in Numerical Analysis courses, addressing three persistent challenges: high cognitive load from abstract algorithms, limited unidirectional classroom interaction, and the gap between al-

gorithmic understanding and practical application.

The framework's four dimensions—knowledge graph-based intelligent curriculum restructuring, ternary synergy teaching model construction, virtual-real integrated smart learning environment development, and multidimensional intelligent assessment systems—offer a coherent response to these challenges. By transforming the traditional binary classroom into a ternary synergistic ecosystem where AI serves as a “capability enhancer” and “thinking accelerator,” the framework leverages AI to enhance rather than replace human teaching.

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Author Contributions

Conceptualization, W.W. Xu; methodology, W.W. Xu; validation, W.W. Xu; formal analysis, X.D. Li; investigation, X.D. Li; data curation, Q. Guo; writing—original draft preparation, X.L. Wang and M. Yang; writing—review and editing, X.D. Li; funding acquisition, W.W. Xu and X.D. Li. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

- Dalian University of Technology (2026). *Digital Intelligence Reconstructs Classroom Ecology, Ternary Interaction Empowers Education*. <https://news.dlut.edu.cn/>
- Liaocheng University Dongchang College (2026). *Dual-Core Driven: Smart Course Construction and Discipline (Subject) Engine Building under Teacher-Student-AI Ternary Synergy. Special Training Program*. <https://news.lcudcc.edu.cn/info/1003/7430.htm>
- Ministry of Education of the People's Republic of China (2025a). *National Digital Education Strategic Action 2.0*. MOE.
- Ministry of Education of the People's Republic of China (2025b). *AI General Education Guidelines for Primary and Secondary Schools (2025 Edition); Guidelines for the Use of Generative AI by Primary and Secondary School Students (2025 Edition)*. MOE. http://www.moe.gov.cn/fbh/live/2025/56916/mtbd/202505/t20250512_1190194.html
- Ministry of Education of the People's Republic of China, et al. (2025c). *Opinions on Accelerating the Digitalization of Education (Jiao Ban [2025] No. 3)*. MOE.
- Piao, H. Y., & Huang, B. L. (2025). Research on the Reconstruction of School Classroom Ecological System in the Digital Intelligence Era. *Huaxia Teacher*, No. 25, 3-6. (In Chinese)

- Shandong Provincial Department of Education (2025b). *Interpretation of the Shandong Province “AI+ Education” Implementation Plan*. Shandong Provincial Department of Education. http://edu.shandong.gov.cn/art/2025/7/3/art_107055_10341362.html
- Shandong Provincial Department of Education, et al. (2025a). *Shandong Province “AI+ Education” Implementation Plan (Lu Jiao Shu Zi [2025] No. 2)*. Shandong Provincial Department of Education. http://edu.shandong.gov.cn/art/2025/7/3/art_107059_10341364.html
- Tongji University (2025). Teachers, Agents, and Students Achieve Ternary Synergy for Knowledge Co-Creation—Tongji University Presents a New Vision of Future Classrooms. *Shanghai Science and Technology News*. (In Chinese)
- Xu, Y. H., & Zhang, L. P. (2025). Teaching Design and Case Study of Numerical Iteration Methods Based on Generative AI—A Case of the Numerical Analysis Course. *Advances in Education*, 15, 587-596. (In Chinese) <https://doi.org/10.12677/ae.2025.1581478>
- Xu, Y., Nan, Y., Xu, J. M., & You, H. B. (2026). Exploration of the “Teacher-Student-Machine” Collaborative Teaching Model—A Case Study of Practical Teaching in Programming Courses. *Advances in Education*, 16, 1321-1327. (In Chinese) <https://doi.org/10.12677/ae.2026.1661262>
- Yin, X. L., Zhao, C. Y., Li, Q. P., & Kong, S. X. (2025). Practical Teaching Reform of Numerical Analysis Course Based on OBE Concept. *Journal of Higher Normal Science*, 45, 57-63. (In Chinese)
- Zhang, J. (2025). “Teacher-Student-Machine” Ternary Interaction: Research on the Innovative Teaching Model of Numerical Analysis Course Design Empowered by AI. *Creative Education Studies*, 13, 292-299. (In Chinese) <https://doi.org/10.12677/ces.2025.1311869>
- Zhang, L. (2024). Exploration of Integrating AI Technology into the Numerical Analysis Course. *Science and Technology Wind*, No. 34, 47-49.
- Zhang, Y. J., Wang, J., & Li, W. M. (2025). AI-Enhanced Curriculum Reform in Numerical Analysis: Exploration and Practice—A Case Study of Graduate Numerical Analysis in Engineering and Science. *Advances in Education*, 15, 187-194. <https://doi.org/10.12677/ae.2025.15122263>
- Zhou, C. R., & Ning, L. S. (2026). Research on Teaching Reform of the “Numerical Analysis” Course under the Background of Artificial Intelligence and Big Data. *Science and Technology Wind*, No. 1, 125-127. (In Chinese)