International Education Forum, 2025, Volume 3, Issue 11
http://ojs.bbwpublisher.com/index.php/IEF
Online ISSN: 2981-8605
Print ISSN 3083-4902

Research on Bottlenecks and Breakthrough Strategies for Improving the Teaching Competence of Higher Vocational Mathematics Teachers in the AI Era

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Abstract: Against the backdrop of education reform driven by artificial intelligence (AI), higher vocational mathematics teaching presents new characteristics such as digitalization, intellectualization, integration, and practicalization. However, the improvement of teachers' corresponding teaching competence faces bottlenecks, including the lag in updating teaching concepts, superficial application of AI technology, insufficient curriculum adaptability, lack of ethical literacy, and weak support for teaching environments. To address these bottlenecks, this paper proposes breakthrough strategies: combining external support with internal incentives, integrating AI throughout the teaching process with precise teaching empowerment, combining competence-oriented development with literacy cultivation, combining risk identification with ethical construction, and combining technical support with teacher development. These strategies provide references for improving the teaching competence of mathematics teachers in higher vocational colleges and support for cultivating high-quality technical and skilled talents in the intelligent era.

Keywords: Higher vocational mathematics teachers; Teaching competence; Bottlenecks; Strategies; AI era

Online publication: December 3, 2025

1. Introduction

As a public basic course in higher vocational colleges, higher vocational mathematics plays a crucial role in cultivating students' scientific literacy, comprehensive abilities, and sustainable development capabilities. It lays the foundation for students to achieve higher-quality employment, entrepreneurship, and better career development [1]. However, current higher vocational mathematics teachers are facing multiple challenges, such as the lag in updating teaching concepts, insufficient ability to apply AI technology, and weak adaptability in curriculum reconstruction. Based on this, the authors investigated 56 domestic higher vocational colleges, systematically explored the bottlenecks in improving the teaching competence of higher vocational mathematics teachers in the AI era, and proposed targeted breakthrough strategies. This research not only helps promote the modernization transformation of the higher vocational mathematics teaching team but also holds great significance for building a higher vocational mathematics teaching system that meets the needs of the intelligent era and improving the quality of talent cultivation.

2. Bottlenecks in improving the teaching competence of higher vocational mathematics teachers in the AI era

To obtain first-hand information on the bottlenecks restricting the improvement of higher vocational mathematics teachers' teaching competence in the AI era, the authors conducted a questionnaire survey (supplemented by direct visits in some colleges) with mathematics teachers in higher vocational colleges as the main respondents (supplemented by student surveys in some colleges). The questionnaire was designed from five perspectives—"digital-intelligent teaching concepts, digital-intelligent teaching skills, digital-intelligent curriculum development, digital-intelligent ethical literacy, and digital-intelligent support mechanisms"—to identify the difficulties and problems faced by higher vocational mathematics teachers in improving their teaching competence in the AI era, thereby analyzing the bottlenecks that restrict the improvement of their teaching competence.

2.1. Difficulties in transforming AI-driven digital-intelligent teaching concepts and insufficient internal motivation of teachers

Factors such as the solidification of traditional teaching cognition and the long feedback cycle of digital-intelligent teaching effects have led some mathematics teachers to feel intimidated by new technologies. This makes it difficult for them to update their teaching concepts and results in insufficient internal motivation [2].

Questionnaire results show that 63.3% of teachers adopt a wait-and-see attitude towards digital-intelligent teaching, and 61.6% have cognitive biases towards digital teaching. They fail to recognize that higher vocational mathematics teaching models need to upgrade towards data-driven and personalized learning in the AI era. For example, when teaching "Probability and Statistics", some teachers still prefer the traditional model of "formula derivation + exercise training + simple application." The survey also found that 27.5% of teachers worry about being unable to master intelligent teaching tools and tend to stick to traditional methods. They believe that digital-intelligent teaching requires long-term adjustments to teaching plans and tracking of students' learning effects, while improvements in students' academic performance or teaching evaluations are difficult to achieve in the short term.

2.2. Inadequate integration of AI technology with mathematics teaching and superficial application of technology

Most higher vocational mathematics teachers only apply AI technology at the "low-level auxiliary" level. They lack an understanding of AI application scenarios related to students' majors and fail to integrate AI with the core characteristics of higher vocational mathematics, "emphasizing practice and strengthening application."

Survey results indicate that 72.3% of higher vocational mathematics teachers believe that having AI tools is sufficient, and in-depth application is not important. For instance, they only use AI to generate exercises and grade objective questions, but do not use intelligent platforms to capture learning data during students' project-based learning, such as time spent solving practical problems, types of errors, and mastery of knowledge points. 10% of mathematics teachers report rarely or never using digital-intelligent technology in teaching activities. Additionally, 70.3% of teachers lack the ability to use AI to “integrate mathematics with majors.” For example, they cannot apply calculus to optimize algorithms in intelligent logistics scheduling or solve stress analysis in mechanical design for the mechatronics major.

2.3. Adaptation gaps in AI-integrated mathematics curriculum development, restricting the achievement of teaching objectives

Higher vocational mathematics teachers face significant “adaptation gaps” in AI-integrated mathematics curriculum development, which are specifically reflected in three aspects: knowledge objectives, competence objectives, and ideological and political (IP) objectives.

First, from the perspective of knowledge objectives: Higher vocational mathematics aims to enable students to acquire mathematical knowledge, mathematical thinking methods, and common mathematical software skills required for various professional courses. It also needs to help students with different foundations make up for knowledge gaps and achieve hierarchical improvement. However, the content adaptation defects of AI-integrated mathematics curriculum resources make it difficult for teachers to advance this goal. 65.2% of teachers report that, due to the actual situation of higher vocational students—“uneven mathematical foundations and diverse learning motivations”—the established AI-integrated mathematics content cannot accurately capture differences in students’ foundational levels. Second, from the perspective of competence objectives, AI development teams lack in-depth research on the talent cultivation goals and post-competence requirements of various majors in higher vocational colleges. As a result, intelligent teaching content remains basically at the level of general mathematical knowledge. Third, from the perspective of IP objectives: Approximately 71.4% of teachers believe that current AI-integrated mathematics courses lack the integration of ideological and political elements, making it difficult for students to perceive the curriculum-based ideological and political education embedded in higher vocational mathematics.

2.4. Insufficient AI risk identification and ethical literacy, and a lack of risk management links

Currently, risks such as data security issues, algorithmic bias, and over-reliance on technology are gradually emerging. Risks related to infringement, ethical norms, and privacy protection also exist simultaneously. Higher vocational mathematics teachers lack the ability to identify potential risks in teaching and have insufficient ethical literacy, leading to a gap between cognition and practice.

First, awareness of preventing data security and privacy leakage risks is weak [3]. When AI teaching systems collect information such as students’ mathematical problem-solving data and learning behavior trajectories, they involve a large amount of personal privacy data. However, 88.2% of mathematics teachers state that they have not received data security training and lack a clear understanding of how to standardize the use of student data and prevent information leakage. Second, the risk of teachers’ cognitive bias is ignored. When guiding students to use AI, teachers do not deeply identify the risk of cognitive bias that students may develop, such as “over-relying on AI for problem-solving” while neglecting mathematical logical deduction.

2.5. Inadequate guarantee for the AI teaching environment and a lack of systematic support

The lack of systematic support for the teaching environment also directly restricts the improvement of mathematics teachers' digital-intelligent teaching competence [4].

The survey finds that some colleges only deploy AI teaching equipment in a few multimedia classrooms. This cannot support the practical teaching needs of public basic courses like higher vocational mathematics, such as "Virtual Reality (VR) + Mathematical Modeling" and "AI Image Recognition + Professional Scenario Analysis for Mathematical Application." As a result, the AI-supported teaching of "learning mathematics" and "applying mathematics" in higher vocational education becomes a mere formality. There are also obvious loopholes in the service support system. Most colleges lack full-time AI teaching technology support teams, and some complex problems cannot be effectively solved because "technology teams do not understand mathematics teaching."

3. Breakthrough strategies for improving the teaching competence of mathematics teachers in higher vocational colleges in the AI era

3.1. Concept transformation: Combining external support with internal incentives

3.1.1. Strengthen top-level design and improve incentive mechanisms

Schools must carry out institutional innovation, explicitly incorporating AI teaching application capabilities into teachers' performance evaluation, professional title assessment, and selection for awards and recognition. Establish special funds and rewards to provide substantive recognition or incentives for teachers who successfully develop digital teaching resources and conduct digital-intelligent teaching.

3.1.2. Establish "AI Teaching Innovation Teams" and build teacher learning communities

Create a positive atmosphere where "there are leaders to take the lead and partners to walk with" to reduce teachers' sense of loneliness and fear. Encourage interdisciplinary cooperation, especially pairing mathematics teachers with computer major teachers to form a mutual assistance model of "technical experts + teaching experts." Enhance professional confidence and a sense of mission through concept guidance and case demonstrations.

3.1.3. Promote in phases and set up demonstration models

Lower the initial threshold to allow teachers to experience the convenience brought by technology and gradually develop usage habits. Focus on cultivating and vigorously promoting successful cases that take the lead in national high-quality online courses to play their radiating and leading role. Use people and events around them to stimulate the internal motivation of more teachers to think, "I want to try too."

3.2. Identify entry points: Combining full-process integration with precision teaching empowerment

3.2.1. Integrate mathematics with majors to identify the entry point for the integration of AI and mathematics

The key to integration is to avoid "technology for technology's sake"; it needs to be combined with professional integration and find suitable AI tools [5–6]. For example, for mechanical and architectural majors, AI-driven 3D modeling tools can be used to demonstrate "part section analysis" and "engineering volume calculation" in solid geometry, transforming abstract mathematical knowledge into practical problems perceivable in professional posts.

3.2.2. Promote in-depth application of AI technology through the "pre-class, in-class, post-class" full process

Before class, conduct a precise diagnosis to customize preview plans, and use AI teaching platforms to issue diagnostic tests to build accurate "mathematical learning digital profiles" for each student. During class, normalize flipped classrooms and empower interaction with AI: use AI tools to integrate professional scenarios into higher vocational mathematics teaching, and explain targeted content, such as "modeling steps" that students easily make mistakes in, to improve classroom efficiency. After class, students use AI to complete mathematics practical assignments combined with their majors, and receive 24-hour tutoring from AI teaching assistants.

3.2.3. Conduct project-based learning and innovate AI-simulated mathematical models

Carry out practical project-based learning combined with AI, and use AI to simulate and construct mathematical models. For example, when teaching differential equations, simulate models such as epidemic spread and population growth to cultivate students' modeling capabilities and innovative capabilities [7–9].

3.3. Intelligent adaptation: Combining competence orientation with literacy cultivation

3.3.1. Build an intelligent academic diagnosis system for mathematics courses to achieve precise adaptation to knowledge objectives

Given the significant differences in higher vocational students' mathematical foundations, develop an intelligent academic diagnosis platform for higher vocational mathematics based on big data. This platform integrates multi-dimensional data from pre-class preparation, in-class learning, and assignments, establishes dynamic evaluation profiles for students, and designs flexible knowledge graphs.

3.3.2. Deepen industry-education integration to promote competence development

Construct a vocational competence-oriented AI mathematics curriculum system to support professional needs [10]. Specific measures include: investigating professional teaching and research sections; organizing mathematics teachers to conduct in-depth surveys in industrial enterprises to sort out lists of mathematical competencies required by various majors; collaborating with enterprise technicians to develop a library of real project cases; and designing problem-oriented intelligent teaching modules. Meanwhile, establish a dynamic update mechanism to adjust curriculum content regularly based on industrial and technological development.

3.3.3. Innovate the integration of ideological and political (IP) elements to strengthen the function of value guidance

Highlight value guidance, establish an IP education map for courses, and closely integrate this map with AI mathematics curriculum resources [11]. Integrate IP elements from three perspectives—disciplinary characteristics, integration of mathematics and majors, and social practice—to achieve positive guidance and feedback on students' values.

3.4. Human-machine collaboration: Combining risk identification with ethical construction

3.4.1. Strengthen risk identification and ethical literacy to build a solid safety defense line

Launch “theory + practice” dual-module training. The theory module focuses on interpreting laws and policies such as the Data Security Law of the People’s Republic of China and analyzing typical data leakage cases. The practice module trains practical skills—such as data permission setting and algorithm bias identification—through simulating mathematics application teaching scenarios. Additionally, establish a certification mechanism for teachers’ AI ethical literacy.

3.4.2. Innovate human-machine collaboration models to balance AI and teaching autonomy

Guide students to understand the advantages and limitations of AI, and implement a two-stage process of “AI assistance + independent problem-solving” for students to avoid weakening their independent thinking abilities [12]. At the same time, guide students to understand AI correctly and rationally, and cultivate their critical thinking. Clearly define the boundaries for teachers’ use of AI tools, add a “teaching reflection on AI use” section in teaching design, and establish a community of mathematics teachers for research and training. Improve teachers’ independent teaching design capabilities through methods such as “same lesson, different designs” (teaching the same content with different approaches).

3.4.3. Improve emergency response and management mechanisms to build a safety governance system

First, formulate the Contingency Plan for AI Teaching Emergencies, clarify response procedures for scenarios such as system failures (e.g., parameter abnormalities) and data leakage, and ensure teachers master the operation of the plan proficiently [13]. Second, establish a school-level AI teaching risk assessment team to promptly issue early warnings and rectify behaviors such as illegal upload of private data and over-reliance on AI for lesson preparation.

3.5. Foundation consolidation: Combining technical support with teacher development

3.5.1. Strengthen infrastructure and resource construction to consolidate hardware and software foundations

First, include the procurement of AI teaching hardware in the school’s annual key budget, prioritize equipping professional practice venues and mathematical modeling laboratories with VR equipment and AI interactive terminals, and upgrade existing multimedia classrooms [14]. Second, abandon generalized content and develop AI mathematics resources centered on the professional characteristics of higher vocational education. For example, design a module of “AI image recognition + part size calculation” for mechanical majors, and develop a case library of “AI data analysis + mathematical modeling” for finance and economics majors to ensure the practicality and targeting of resources.

3.5.2. Build a professional technical support and service team to provide sustained and effective guarantees

It is recommended to establish a school-level “AI Teaching Support Center”, build an online support platform and a work order system, and ensure teachers receive immediate assistance when encountering problems such as deviations in academic analysis and system failures. Meanwhile, establish a regular inspection and maintenance mechanism to identify potential technical risks in advance.

3.5.3. Improve teacher training and development systems to strengthen systematic support and effect tracking

Design hierarchical and classified systematic training programs [15]. Based on the needs of teachers with different professional backgrounds, ages, and skill levels, offer a series of courses ranging from basic technical operations to in-depth innovative applications. Strengthen post-training follow-up guidance to effectively improve teachers' digital-intelligent teaching capabilities.

4. Conclusion

Improving the teaching competence of higher vocational mathematics teachers in the AI era is the cornerstone for enabling students to shift from "learning mathematics" to "applying mathematics", promoting better alignment of higher vocational mathematics with professional needs and industrial development. It is also a strategic fulcrum for cultivating high-quality technical and skilled talents adapted to the intelligent era. Combining the new characteristics of higher vocational mathematics teaching in the AI era, this paper deeply analyzes the bottlenecks restricting the improvement of higher vocational mathematics teachers' teaching competence and proposes systematic breakthrough strategies. These efforts aim to truly realize "promoting learning through application and empowering with intelligence" in higher vocational mathematics teaching, and inject "mathematics + AI" momentum into the high-quality development of vocational education.

Funding

2024 National Online Quality Course for Vocational Education: Applied Higher Mathematics

2024 Second Batch of Teaching Reform Projects for Higher Vocational Education in Zhejiang Province during the "14th Five-Year Plan" Period: "Research on Strategies for Improving the Teaching Competence of Higher Vocational Teachers in the Digital and Intelligent Era" (Project No.: jg20240057)

Disclosure statement

The authors declare no conflict of interest.

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