Curriculum and Teaching Methodology (2026)
Clausius Scientific Press, Canada

DOI: 10.23977/curtm.2026.090504
ISSN 2616-2261 Vol. 9 Num. 5

Construction and Practice of an AI-Driven Six-Stage Closed-Loop Teaching Model for Mathematics in Vocational Undergraduate Education

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Keywords: Vocational Undergraduate Education; Advanced Mathematics; Closed-Loop Teaching Model; Precision Teaching; Teaching Model Reform

Abstract: Advanced Mathematics teaching in many vocational universities in China still follows traditional instructional paradigms, with practical problems including subjective learning-condition diagnosis, superficial implementation of differentiated instruction, inadequate alignment between teaching resources and professional occupational contexts, an excessive emphasis on summative assessment over formative assessment, and passive and delayed instructional adjustment. Homogeneous and standardized traditional classrooms are therefore insufficient to meet the needs of vocational undergraduate students, who exhibit substantial differences in prior mathematical knowledge, diverse professional orientations, and strong practical learning needs. To address these challenges, this study, against the backdrop of smart education, fully explores the application of artificial intelligence (AI) and big data technologies in education and develops an AI-driven six-stage closed-loop teaching model consisting of precise diagnosis, dynamic stratification, resource recommendation, tiered instruction, multidimensional assessment, and iterative adjustment. The model is implemented in Advanced Mathematics in vocational undergraduate education. By leveraging AI for learning-condition data collection and analysis, intelligent adaptation of learning resources, dynamic monitoring of learning status, and iterative optimization based on instructional data, the model connects the entire teaching process before, during, and after class, facilitating a transition in mathematics instruction from homogeneous knowledge transmission to precision-oriented student development and empowerment. Practical implementation indicates that the proposed model can effectively improve classroom teaching effectiveness, strengthen students' ability to apply mathematical knowledge, and better fulfill the talent cultivation objectives of vocational undergraduate education. It therefore provides a practical reference for smart teaching reform in mathematics at similar universities.

1. Introduction

Vocational undergraduate education constitutes an important component of China's modern vocational education system. It differs from conventional undergraduate education, which places greater emphasis on academic research, while extending beyond the associate-degree level of vocational education in terms of educational objectives and competency requirements. Its primary goal is to cultivate high-level technical and skilled professionals with solid theoretical foundations, strong engineering and practical competencies, and well-developed professional qualities. As a public foundational course offered to students majoring in science and engineering, economics, management, and related fields, Advanced Mathematics undertakes a dual educational function. On the one hand, it develops students' abilities in logical reasoning, abstract modeling, and quantitative analysis. On the other hand, it provides essential computational tools, modeling approaches, and analytical methods for subsequent courses in such fields as mechanical engineering, electromechanical engineering, computer science, engineering, big data, economics, and management. Consequently, the quality of Advanced Mathematics instruction directly affects students' depth of understanding of professional courses and their capacity to apply technical knowledge in occupational contexts.

From the perspective of current teaching practice, Advanced Mathematics instruction in many vocational undergraduate universities continues to rely heavily on traditional lecture-based approaches. Classroom teaching generally centers on teachers' explanations of concepts and theorems, formula derivations, worked examples, and post-class exercises, resulting in a teaching process characterized by linearity, fragmentation, and rigidity rather than a coherent closed-loop system. At the student level, vocational undergraduate students come from diverse educational backgrounds and often demonstrate substantial differences in their prior mathematical knowledge. Some students have significant gaps in foundational mathematical knowledge, low confidence in mathematics, and limited learning initiative. The students tend to passively receive knowledge in class and mechanically complete exercises after class, with insufficient active thinking and limited awareness of knowledge transfer. At the instructional level, teaching content is often directly adapted from conventional undergraduate textbook systems, with excessive emphasis on theoretical derivations and insufficient integration of mathematical applications into professional and occupational contexts. As a result, students may perceive mathematics as difficult to learn and disconnected from practical needs, leading to a cycle in which they struggle to master mathematical knowledge, fail to recognize its practical value, and gradually lose motivation to learn [1-3].

With the deepening integration of emerging artificial intelligence, big data technologies, and educational practices, smart teaching, individualized instruction, and precision-oriented student development have become important directions for curriculum reform in vocational undergraduate education. These developments also provide new technological approaches to addressing persistent challenges in public foundational courses. Constrained by limited technological tools, traditional teaching practices often require teachers to infer students' learning conditions primarily from classroom observations and assignment performance, making it difficult to comprehensively identify individual students' knowledge gaps, learning habits, and competency deficiencies. Static grouping is likewise insufficient to accommodate dynamic changes in students' learning status. Moreover, teaching, learning, assessment, and improvement are often disconnected from one another, while instructional optimization tends to depend on teachers' post-class reflection and experience rather than objective and systematic learning data [4-6].

Against this background, this study takes Advanced Mathematics in vocational undergraduate education as its research context and, guided by the principles of smart education, employs digital tools such as AI-based student learning profiles, intelligent resource recommendation, and full-process data monitoring to reconstruct the logic of course instruction and develop a six-stage closed-loop teaching model. Covering the complete instructional process before, during, and after class, the model promotes the digital, precise, and individualized development of mathematics teaching in vocational undergraduate education. It aims to address practical problems including inaccurate understanding of students' learning conditions, difficulties in implementing differentiated instruction, weak connections between mathematical learning and professional applications, and overly simplistic assessment, thereby improving the educational quality and effectiveness of foundational mathematics courses.

2. Challenges in Traditional Mathematics Teaching in Vocational Undergraduate Education

2.1 Rigid Teaching Models and the Weakening of Students' active role

Traditional Advanced Mathematics classrooms generally center on standardized instruction. The syllabus, teaching schedule, classroom content, and post-class exercises are largely predetermined, while instructional design relies heavily on teachers' individual teaching experience. However, students within the same class often differ substantially in their prior mathematical knowledge. It is difficult for teachers to conduct a detailed assessment of each student's level of knowledge acquisition, and judgments concerning students' knowledge gaps and weaknesses in mathematical thinking are therefore often subjective and incomplete. Under a homogeneous classroom model characterized by unified content and pacing, a clear divergence between students tends to emerge. Students with weak mathematical foundations may struggle to keep pace with classroom instruction, accumulate knowledge gaps, and gradually lose confidence in learning. In contrast, students with stronger foundations may find the instructional content insufficiently challenging and lack opportunities for further exploration and advanced practice, leaving their learning potential underdeveloped. As students' differentiated learning needs receive insufficient attention, the principle of student-centered individualized instruction often remains at the conceptual level and is difficult to translate into effective classroom practice.

2.2 Disconnection between Learning and Application and Insufficient Integration of Professional Contexts

Mathematics instruction in vocational undergraduate education should serve the objectives of professional talent cultivation. However, the current provision of mathematics teaching resources in many institutions remains relatively standardized and inflexible. Teaching materials are primarily derived from textbooks, courseware, and standardized exercise sets, with insufficient scenario-based and application-oriented resources tailored to different professional fields. Teaching resources are generally provided in a uniform manner without differentiated recommendations based on students' prior knowledge or professional orientations. Classroom instruction tends to emphasize theorem proofs and formula manipulation, while engineering cases and occupational application scenarios are insufficiently integrated into teaching. Consequently, students often have difficulty understanding how mathematical knowledge can be applied in subsequent professional courses or future occupational contexts. When students fail to perceive a meaningful connection between mathematics and their own professional fields, their intrinsic motivation to learn is weakened, and the development of mathematical application and modeling abilities is consequently constrained. The professional and practical characteristics of mathematics courses in vocational undergraduate education are therefore insufficiently manifested.

2.3 Fragmented Teaching Processes and the Lack of Dynamic Closed-Loop Design

Traditional teaching processes are often fragmented, with pre-class preparation, classroom instruction, and post-class assignments and review functioning as relatively independent components without effective data integration. Systematic diagnosis of students' learning conditions is often lacking before class, real-time monitoring of learning status is insufficient during class, and data-based review and reflection are limited after class. Once an instructional plan has been established, it generally remains unchanged throughout a chapter or even an entire semester, making it difficult to dynamically adjust teaching priorities, instructional pacing, and levels of difficulty according to students' actual mastery of knowledge. Teaching improvement largely depends on teachers' subjective perceptions and retrospective reflection, with insufficient support from objective learning data. As a result, knowledge gaps accumulated during earlier stages of learning may persist and become increasingly difficult to address, while instructional problems cannot be identified and corrected in a timely manner, thereby reducing overall teaching effectiveness.

2.4 Single-Dimensional Assessment and the Weakening of Formative Educational Functions

In many universities, assessment in Advanced Mathematics remains dominated by summative examinations at the end of the semester, while formative assessment accounts for a relatively small proportion of the overall grade. Assessment indicators are often relatively simple and general, making it difficult to comprehensively capture students' learning processes, including pre-class preparation, classroom interaction and reflection, quality of exercise completion, correction of errors, and engagement with extended learning resources. Assessment results are primarily used to determine course grades and therefore mainly reflect students' performance on a final examination rather than their learning attitudes, development of mathematical thinking, and growth in competencies. Such an assessment approach also makes it difficult to accurately identify individual students' learning deficiencies. Furthermore, assessment results are not sufficiently fed back into instructional design or individualized student support. Consequently, the educational functions of assessment in promoting teaching and learning are not fully realized.

3. Construction of an AI-Driven Six-Stage Closed-Loop Teaching Model for Mathematics in Vocational Undergraduate Education

3.1 Precise Diagnosis

A precise diagnosis of students' learning conditions is the logical starting point of precision teaching and is usually carried out before class. With the support of an AI-enabled smart teaching platform, a variety of approaches are integrated to collect information about students' learning from multiple dimensions. These approaches include diagnostic pre-assessments, the collection of pre-class learning data, and the analysis of historical assignment and examination data. The system collects data concerning students' existing mathematical foundations, distribution of frequently misunderstood or incorrectly answered knowledge points, problem-solving accuracy, response time, completion of pre-class learning resources, and learning behavior patterns. Based on these data, the platform automatically generates individual student learning profiles and an overall class-level learning analysis report. Individual profiles identify each student's specific knowledge gaps, while class-level reports summarize common errors and knowledge points that remain insufficiently mastered across the class. This approach shifts the diagnosis of learning conditions from teachers' experience-based judgments toward data-informed analysis, enabling the identification of both common learning difficulties and individual weaknesses. It therefore provides an objective basis for subsequent dynamic stratification, personalized resource recommendation, and the design of classroom teaching priorities, establishing a teaching logic of 'diagnosis before instruction.'

3.2 Dynamic Stratification

Based on AI-generated learning analysis reports, the platform automatically stratifies and groups students according to their levels of knowledge mastery, problem-solving abilities, learning behaviors, and developmental potential. Students are categorized into three levels: the foundational consolidation level, the competency enhancement level, and the innovation and extension level. Unlike static stratification conducted once at the beginning of a program, the proposed model incorporates dynamic mobility among levels. AI continuously collects process data from classroom responses, learning tasks, post-class assignments, and unit assessments, periodically reevaluates students' learning and competency development, and automatically adjusts their assigned levels. Students are therefore allowed to move between levels according to their learning progress, reducing the risks of fixed labeling and negative psychological effects associated with static stratification.

Based on the stratification results, the teachers establish differentiated knowledge objectives, competency objectives, and learning-quality objectives for each level. The foundational consolidation level focuses primarily on strengthening fundamental concepts and basic computational skills; the competency enhancement level emphasizes deeper understanding of mathematical knowledge and the application of relevant methods; and the innovation and extension level focuses on comprehensive modeling, engineering applications, and innovative thinking. Differentiated instructional designs can thus be developed for each level, facilitating the practical implementation of individualized instruction.

3.3 Resource Recommendation

By leveraging AI-based data analytics and integrating students' stratification results with their identified learning deficiencies, the proposed model enables personalized, precise, and differentiated distribution of teaching and learning resources. For students at the foundational consolidation level, the platform recommends micro-lectures on fundamental concepts, knowledge-point checklists, basic exercises, and explanations of common errors to help strengthen foundational knowledge. For students at the competency enhancement level, it recommends representative worked examples, problem-solving strategies, and basic application cases related to students' professional fields, thereby strengthening their ability to apply mathematical knowledge. For students at the innovation and extension level, it provides advanced exercises, cutting-edge mathematical applications in relevant professional fields, and engineering-oriented practical cases to foster higher-order application and innovation capabilities. At the same time, learning resources are adapted to students' specific professional orientations by incorporating mathematical application scenarios from relevant industries, thereby highlighting the vocational and practical characteristics of mathematics education in vocational undergraduate programs.

3.4 Tiered Instruction

Building on AI-based learning stratification and adaptive resource recommendation, differentiated tiered instruction is implemented in the classroom. During the introductory stage, cases are designed according to different professional contexts and adapted to the cognitive levels of students at different learning levels. During focused knowledge instruction, common learning difficulties are addressed through unified explanations, while individualized weaknesses are addressed through targeted guidance and clarification. During classroom practice, differentiated exercises are assigned: students at the foundational level focus on formula application and basic computation; students at the competency enhancement level focus on variations of problem types and methodological synthesis; and students at the innovation and extension level focus on comprehensive applications and professional practice scenarios.

Meanwhile, smart classroom interaction tools are used to facilitate differentiated questioning, inquiry-based learning, and individualized guidance. This approach accommodates the learning needs of students with different levels of prior knowledge and addresses the limitations of traditional homogeneous instruction, in which high-performing students may not receive sufficient challenges while students with weaker foundations struggle to keep up.

3.5 Multidimensional Assessment

The AI-enabled smart platform continuously collects data throughout the teaching process and establishes a multidimensional assessment system integrating formative and summative assessment. Assessment dimensions include completion of pre-class preparation, performance in diagnostic assessments, participation in classroom interactions, quality of differentiated learning tasks, correction of errors, time spent on post-class learning resources, effectiveness of differentiated assignments, and final examination performance.

The AI system automatically quantifies these assessment data and generates individual student learning reports and class-level teaching-quality analysis reports, thereby moving beyond the traditional assessment model dominated by a single summative examination. Multidimensional data-based assessment provides a more comprehensive representation of students' learning attitudes, knowledge mastery, and competency development, while also objectively identifying weaknesses in classroom instruction. In this way, assessment can perform its functions of motivation, diagnosis, and instructional guidance more effectively.

3.6 Iterative Adjustment

Iterative adjustment constitutes the core of the closed-loop teaching model. By integrating AI-generated assessment data with dynamic changes in students' learning conditions, the model supports continuous optimization throughout the teaching process. Based on learning analysis reports, assessment data, error statistics, and feedback on resource use generated by the platform, teachers can systematically identify weaknesses and deficiencies in instruction at the lesson and stage levels and subsequently adjust instructional plans, stratification criteria, resource content, and teaching pace in a targeted manner.

At the same time, the AI system dynamically updates students' learning levels and personalized resource repositories according to their progress over successive learning stages. This process forms a dynamic cycle of learning diagnosis → instructional implementation → data-based assessment → instructional adjustment → renewed instruction. Through this iterative mechanism, the model establishes a sustainable and intelligent approach to instructional optimization, enabling teaching quality to be continuously improved through successive cycles of data-informed adjustment.

4. Analysis of the Practical Effects of the AI-Driven Closed-Loop Teaching Model

4.1 Enhanced Student Learning Engagement and Initiative

The six-stage closed-loop teaching model changes the passive learning pattern commonly observed in traditional mathematics classrooms and encourages students to become more active participants in the learning process. Personalized resource recommendations before class lower the entry threshold for students with weaker mathematical foundations, while the dynamic mobility mechanism between learning levels protects students' self-confidence and motivation by allowing them to move to higher levels as their learning performance improves. In-class tiered learning tasks further enable students with different levels of prior knowledge to experience a sense of achievement through appropriately challenging learning activities.

Compared with the control classes, students in the practice classes demonstrated noticeable improvements in the completion rate of pre-class preparation, participation in classroom interactions, and time spent on independent extended learning after class. Students with weaker foundations showed reduced anxiety and resistance toward mathematics, while higher-performing students were provided with greater opportunities for further exploration. Overall, the classroom learning atmosphere improved, and students' awareness of autonomous learning and mathematical thinking skills were systematically strengthened.

4.2 Continuous Improvement in Classroom Teaching Quality

The proposed model integrates objective learning data throughout the entire instructional process and connects previously fragmented teaching stages, thereby addressing the problems of homogenization, fragmentation, and insufficient feedback and adjustment in traditional mathematics instruction. Pre-class learning diagnosis enables instructional design to target students' actual learning deficiencies; dynamic stratification facilitates the implementation of individualized instruction; real-time classroom data allows teachers to flexibly adjust the pace and focus of instruction; multidimensional assessment identifies weaknesses in the teaching process; and iterative adjustment supports continuous instructional improvement.

Through the interaction and coordination of these components, AI technologies are integrated throughout the teaching process. Compared with the control classes, the practice classes achieved higher pass rates and excellence rates in unit assessments. Students demonstrated more solid mastery of mathematical knowledge, while their ability to use mathematical tools to analyze relatively simple professional problems was also noticeably enhanced. These results indicate simultaneous improvements in both the quality and effectiveness of classroom instruction.

4.3 Strengthened Vocational Orientation of Mathematics Education

The proposed model is grounded in the talent cultivation objectives of vocational undergraduate education and integrates professional and occupational requirements into the entire instructional process on the basis of intelligent teaching technologies. Learning resources, classroom cases, and inquiry-based tasks are adapted to the characteristics of different professional fields, thereby establishing a connection between fundamental mathematical knowledge and professional practice and reducing the separation between public foundational courses and specialized courses.

Through exposure to professional application scenarios, students can more directly recognize the practical value of mathematics in their professional studies and future occupational activities. Mathematics instruction therefore moves beyond the simple transmission of formulas and theorems toward the coordinated development of mathematical thinking, mathematical tool application, and professional competencies. This approach is more closely aligned with the cultivation of high-level technical and skilled professionals in vocational undergraduate education.

4.4 More Scientific and Comprehensive Teaching Assessment

Based on full-process data collection, the proposed model establishes a dynamic and multidimensional assessment system covering learning activities before, during, and after class. Assessment is no longer based exclusively on final examination scores; instead, students' learning processes, competency development, and individual progress are incorporated into the assessment framework. Because assessment is supported by objective data collected through the teaching platform, the influence of subjective grading is reduced.

Assessment reports provide students with timely feedback on their learning deficiencies and corresponding personalized learning recommendations. At the same time, they provide teachers with evidence for subsequent instructional improvement. Consequently, the proposed model enables assessment to genuinely serve the functions of promoting teaching through assessment, promoting learning through assessment, and promoting instructional improvement through assessment, thereby enhancing the diagnostic, motivational, and developmental value of educational assessment.

5. Conclusions

Artificial intelligence-enabled education represents an important direction for the reform and development of vocational education in the new era and provides a promising pathway for improving the quality of public foundational courses in vocational undergraduate education. This study developed an AI-driven six-stage closed-loop teaching model based on the educational objectives of vocational undergraduate education and supported by big data and artificial intelligence technologies. The model reconstructs the instructional logic of Advanced Mathematics across the entire process before, during, and after class, enabling more precise learning diagnosis, more individualized instructional stratification, more intelligent resource adaptation, more targeted instructional implementation, more multidimensional assessment, and more continuous instructional optimization.

The proposed model addresses several limitations of traditional mathematics teaching in vocational undergraduate education, including homogeneous instruction, insufficient responsiveness to individual learning needs, weak connections between mathematical learning and professional applications, and inadequate feedback and iterative adjustment. By integrating learning diagnosis, dynamic stratification, resource recommendation, tiered instruction, multidimensional assessment, and iterative adjustment into a coherent instructional cycle, the model strengthens the connection between teaching, learning, assessment, and improvement. It also contributes to improving classroom teaching effectiveness and students' ability to apply mathematical knowledge in professional contexts.

Overall, the AI-driven six-stage closed-loop teaching model provides both a theoretical reference and a practical approach for implementing smart teaching reform in public foundational courses in vocational undergraduate education. Its application suggests that the effective integration of AI and educational practice should not be limited to the introduction of technological tools, but should focus more fundamentally on reconstructing instructional processes, improving the precision of teaching decisions, and establishing mechanisms for continuous instructional improvement. Further practice and empirical research are needed to examine the model across different institutions, professional fields, and course contexts and to explore its long-term effects on students' mathematical learning and professional competency development.

Acknowledgements

This work was supported by Hainan Vocational University of Science and Technology Education Reform Project (HKJGZD2025-12).

References

[1] Liu T. (2026). Construction and Practical Validation of a 'Three-Dimensional, Four-Stage' Teaching Model for Artificial Intelligence-Empowered Vocational Education: A Case Study of the 'Community Digital Marketing' Course

[J]. Guangdong Vocational Technical Education and Research, 1, 95-98+110.
[2] Shi L. (2024). Reform and Exploration of Practical Teaching in Higher Mathematics at Vocational Undergraduate Institutions against the Background of the 'Three Educations' Reform, Modern Vocational Education, 1, 45-48.
[3] Huang M., Xie J.M., Huang W., et al. (2025). Exploration and Practice in the Development of a Closed-Loop Teaching Model for Information-Based Instruction, Journal of Higher Education, 5, 13-16.
[4] Ma J., Wang J. (2026). The Theoretical Logic and Practical Pathways for Promoting Individualized Teaching in Vocational Education through Artificial Intelligence, Chinese Vocational and Technical Education, 15, 74-83+92.
[5] Zhao W.P., Song L.L., Cui Z.K. (2026). Transformative Characteristics, Practical Bottlenecks and Optimization Strategies for the Development of Vocational Education Teaching Materials Empowered by Artificial Intelligence [J]. Education and Vocation, 15, 5-13.
[6] Wang Z.Y., Wang Y.Q., Zhou Y.H. (2026). A Study on the Mechanisms by Which Generative Artificial Intelligence Empowers Mathematics Teaching in Vocational Education, Electronic Components and Information Technology, 7, 212-215+223.