

Construction of an AI-Driven Stratified Adaptive Teaching Model for Mathematics in Vocational Undergraduate Education

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Abstract: Against the backdrop of typological orientation and the high-quality development of vocational undergraduate education, the structure of student intake has become increasingly diverse. Significant disparities exist in students' mathematical foundations and learning abilities. Traditional uniform teaching models struggle to effectively meet these differentiated learning needs. Drawing on the principles of stratified instruction, adaptive learning and learning analytics, this study explores the integration of artificial intelligence technologies into mathematics teaching in vocational undergraduate education, with the aim of developing an AI-driven, stratified, adaptive teaching model. Based on a clear delineation of conceptual connotations, the study systematically identifies key features including data-driven decision-making, dynamic adaptation, personalized support and human-machine collaboration. The study also develops a closed-loop operational framework of 'diagnosis-stratification-implementation-feedback-regulation' and explains its operational mechanisms from the perspectives of instructional processes, technological support and organizational forms. The findings indicate that the proposed model enhances instructional precision and process regulation capabilities. However, effectiveness depends on coordinated support in terms of data quality, teachers' digital literacy, a stratified resource system and institutional guarantees.

Keywords: Vocational Undergraduate Education; Mathematics Teaching; Artificial Intelligence; Stratified Instruction; Adaptive Learning; Learning Analytics

1. Introduction

Vocational undergraduate education is primarily oriented toward cultivating high-level technical and skilled talents, emphasizing the coordinated development of knowledge application, technological integration, and practical innovation capabilities. As a foundational and instrumental core course, mathematics plays an irreplaceable role in supporting disciplinary learning, training logical thinking, and enhancing students' overall competencies [1-3]. With the expansion of vocational undergraduate institutions and the diversification of admission channels, student sources have become increasingly heterogeneous, encompassing pathways such as progression from secondary vocational education, higher vocational education, and general college entrance examination admissions [4-6]. Consequently, substantial differences have emerged in students' academic foundations, learning motivations, cognitive strategies, and learning paces, resulting in

pronounced heterogeneity and stratification in mathematics learning.

At present, mathematics teaching in vocational undergraduate education is still predominantly characterized by a standardized model featuring unified objectives, pace, content, and assessment. While this model ensures instructional consistency, it struggles to accommodate the diverse learning needs of students at different levels. Students with weaker foundations are prone to experiencing excessive cognitive load, diminished learning confidence, and a sustained decline in engagement, whereas students with stronger backgrounds often encounter repetitive content, insufficient challenge, and difficulty maintaining motivation. Meanwhile, assessment systems dominated by summative evaluation tend to overlook the value of process-oriented learning data, making it difficult for instructors to timely grasp students' learning states and implement precise interventions [7-9]. As a result, instructional adjustments largely rely on subjective experience, lacking both scientific rigor and timeliness.

With the rapid development of artificial intelligence, big data, and learning analytics technologies, the capacity to collect, process, and utilize educational data has been significantly enhanced, providing robust technical support for data-informed instructional decision-making and the realization of individualized teaching. The deep integration of AI technologies with stratified instruction and adaptive learning to construct a data-driven, dynamically adaptive, and precisely targeted mathematics teaching model has thus become an important direction for reform and quality enhancement in vocational undergraduate mathematics education.

2. Connotation of the AI-Driven Stratified Adaptive Teaching Model

2.1 Conceptual Definition

The AI-driven stratified adaptive teaching model for mathematics in vocational undergraduate education is a composite instructional model developed within the context of educational digitalization. Oriented toward the talent cultivation goals of vocational undergraduate education and grounded in learners' differences in mathematical learning, this model organically integrates learning analytics, intelligent algorithms, instructional decision-making, and classroom implementation. Its core lies in the continuous collection and intelligent analysis of learning data across the entire instructional process-before, during, and after class-to construct dynamic learner profiles and diagnose cognitive levels. Based on these insights, it enables dynamic stratification, adaptive learning pathways, precise resource recommendation, real-time process feedback, and closed-loop instructional regulation, ultimately achieving the goals of baseline attainment, stratified advancement, and personalized development.

From a systemic perspective, the model consists of four interrelated layers: the data layer, the analytics layer, the decision-making layer, and the execution layer. The data layer is responsible for the collection, cleaning, integration, and storage of multi-source learning data. The analytics layer relies on algorithmic models to conduct data processing, feature extraction, and learning diagnosis. The decision-making layer involves teachers formulating stratification schemes and instructional strategies by integrating data insights with pedagogical expertise. The execution layer implements specific teaching activities through the coordination of online platforms and offline classrooms. The coordinated interaction of these four layers supports the dynamic operation and continuous optimization of the instructional system.

2.2 Fundamental Characteristics

In practical application, the AI-driven stratified adaptive teaching model for mathematics in vocational undergraduate education exhibits distinct systemic characteristics. First, data-driven decision-making constitutes its primary feature, whereby instructional decisions shift from experience-based judgment to empirical evidence grounded in objective data such as learning behaviors, task completion, resource access, and assessment outcomes. This transformation effectively reduces subjective bias and enhances the scientific validity and precision of stratification, instruction, and evaluation. Second, dynamic adaptability is reflected in the non-fixed and non-labeling nature of student stratification and learning pathways. Instead, these are continuously adjusted in response to students' learning progress, competency development, and task performance, allowing for fluid movement across different levels and fostering a virtuous cycle of 'learning-informed stratification, stratification-informed instruction, and instruction-driven advancement.'

Third, personalized support is manifested through the provision of differentiated content, tiered tasks, customized resources, and adaptive guidance tailored to students at different levels. This approach simultaneously addresses the consolidation needs of students with weaker foundations and the enrichment demands of high-performing students, ensuring that learners from diverse starting points receive appropriate and effective support. Finally, human-machine collaboration serves as a critical guarantee for the effective operation of the model. Artificial intelligence systems undertake repetitive and computational tasks such as data processing, intelligent recommendation, real-time feedback, and risk alerting, while teachers play a leading role in instructional design, strategic decision-making, classroom facilitation, emotional support, and value guidance. Through the complementary integration of human and technological strengths, the model achieves a synergistic approach to education.

3. Structural Construction of the Teaching Model

3.1 Overall Structure

The AI-driven stratified adaptive teaching model for mathematics in vocational undergraduate education constructed in this study is centered on a closed-loop framework of 'diagnosis-stratification-implementation-feedback-regulation,' highlighting the cyclic, dynamic, and continuously optimized nature of the instructional process. Learning diagnosis relies on multi-source data to generate learner profiles and assess cognitive levels, identifying differences in students' knowledge mastery, competency levels, and learning habits; it serves as the starting point and foundation of the entire system. Dynamic stratification, based on diagnostic results, employs a multi-indicator comprehensive evaluation method to achieve scientific grouping, clarifying instructional objectives and task gradients for each level, thereby transforming learner differences into a basis for instructional design and enabling precise teaching. Instructional implementation, centered on stratified tasks, adaptive content, and blended learning activities, operationalizes differentiated instruction, practice, and guidance, representing the key stage for model realization. Intelligent feedback continuously collects and analyzes process and outcome data, generating multi-level feedback at the individual, group, and class levels, thus verifying learning effectiveness and accurately identifying problems. Optimization and regulation, based on feedback data, refine stratification outcomes, instructional content, learning pathways, and implementation strategies, driving the system into the next iteration cycle. Essentially, the overall structure constitutes a data-driven, closed-loop adaptive instructional system, whose operational logic reflects an iterative process of data collection, analytical diagnosis, strategy generation, implementation, and

feedback-driven optimization.

3.2 Functional Modules

The multidimensional learning diagnosis module transcends the limitations of single-source assessment data by integrating diverse information, including prior knowledge levels, learning duration, frequency of resource access, task completion status, classroom interaction participation, error types, and learning trajectory data. This enables the construction of comprehensive learner profiles and the precise identification of knowledge gaps, competency deficiencies, and potential learning risks.

The scientific dynamic stratification module replaces static grouping approaches with a multi-indicator comprehensive evaluation framework, categorizing students into foundational, intermediate, and advanced levels. It incorporates a flexible mobility mechanism that allows students to move between levels based on their stage performance, effectively safeguarding learning motivation and stimulating autonomous improvement.

The gradient-based adaptive instruction module implements differentiated design in terms of content, difficulty, tasks, and instructional methods aligned with teaching objectives. For each knowledge point, a three-tier task chain-foundational, intermediate, and advanced-is constructed, accompanied by learning resources such as micro-lectures, worked examples, exercises, and discipline-integrated cases of varying difficulty. Supported by intelligent recommendation algorithms, it achieves precise matching between resources and learning pathways, thereby meeting the needs of learners at different levels.

The full-process intelligent feedback module establishes a mechanism integrating real-time feedback, stage-based feedback, and early warning alerts. During class, response and interaction results are displayed in real time; upon completion of units or chapters, stage-based learning reports are generated; and automatic alerts are triggered for issues such as learning delays, low accuracy rates, or abnormal absenteeism, providing a basis for timely instructional intervention.

The professional teacher regulation module emphasizes teachers' context-sensitive decision-making and instructional adjustment capabilities supported by data. Teachers refine algorithmic recommendations through professional judgment, provide targeted one-to-one guidance for specific students, and dynamically regulate classroom pacing, group activities, and instructional focus, ensuring that technological empowerment consistently serves pedagogical objectives and educational values.

4. Operational Mechanisms and Implementation Pathways

4.1 Instructional Process Design

The instructional process of the AI-driven stratified adaptive teaching model follows an integrated three-stage design: pre-class, in-class, and post-class.

In the pre-class stage, data-driven diagnosis and preliminary stratification are central. Teachers assign pre-assessments, preview tasks, and learning condition questionnaires via the learning platform. The system automatically collects data to complete initial diagnosis and stratification. Based on these results, teachers provide stratified preparatory resources, foundational study guides, and prerequisite micro-lectures to support differentiated preparation, reduce cognitive load, and enhance in-class learning efficiency.

The in-class stage focuses on stratified tasks, interactive inquiry, real-time feedback, and targeted

guidance. Gradient-based learning tasks are designed for different levels: foundational-level students focus on conceptual understanding, formula mastery, and basic computation; intermediate-level students emphasize method application, problem variation, and logical reasoning; advanced-level students engage in comprehensive application, problem-solving, and discipline integration. Information technology tools are employed to collect real-time classroom feedback, enabling teachers to provide targeted explanations, scaffolding, and remediation to ensure effective participation for all students.

The post-class stage emphasizes stratified consolidation and continuous refinement of learner profiles. Stratified assignments, extension tasks, and reflective learning activities are assigned. The system automatically completes grading, statistical analysis, and error diagnosis, generating personalized learning reports. Meanwhile, learning data are continuously accumulated to refine dynamic learner profiles, providing a basis for subsequent diagnosis and stratification, thereby forming a complete instructional closed loop.

4.2 Technological Support System

A stable and well-developed technological support system is essential for the effective operation of the model, comprising four main components: an online teaching platform, a learning analytics system, an intelligent recommendation engine, and a data security and privacy protection system.

The online teaching platform serves as the core carrier, supporting resource distribution, learning interaction, assignment assessment, and data collection, and enabling the integration and full-process tracking of online and offline instructional data. The learning analytics system is responsible for data cleaning, feature extraction, level diagnosis, and trend prediction, transforming raw data into visualized and interpretable evidence for instructional decision-making. The intelligent recommendation engine, based on learner profiles and stratification characteristics, enables personalized matching of learning resources, tasks, and pathways, thereby improving learning relevance and efficiency. The data security and privacy protection system spans the entire data lifecycle, ensuring compliance in data collection, storage, usage, and disposal, in accordance with educational data ethics and privacy protection requirements. Overall, the technological system demonstrates strong openness, compatibility, and scalability, allowing adaptation to different disciplines and instructional contexts while supporting continuous model optimization.

4.3 Instructional Organization Forms

The AI-driven stratified adaptive teaching model adopts a blended learning approach that integrates the advantages of online personalized support and offline face-to-face instruction. Offline classrooms focus on the explanation of key and difficult concepts, cognitive skill development, collaborative inquiry, and direct tutoring, thereby strengthening knowledge construction and interaction among teachers and students. Online platforms support preview and review activities, stratified practice, micro-lecture learning, self-assessment, and personalized tutoring, meeting students' needs for autonomous and flexible learning.

In practical implementation, various forms such as stratified group cooperative learning, cross-level peer assistance, and one-to-one targeted tutoring are employed. While ensuring the integrity of course instruction and the attainment of standard learning objectives, these approaches enhance instructional flexibility and precision, achieving an organic integration of collective instruction and individualized guidance.

5. Key Issues in Implementation

During the implementation of the AI-driven stratified adaptive teaching model for mathematics in vocational undergraduate education, multiple practical challenges must be addressed systematically. Data quality directly determines the validity of analytical results and instructional decisions; thus, standardized data collection protocols, cleaning procedures, and quality verification mechanisms must be established to ensure data authenticity, completeness, validity, and timeliness. Clear boundaries for data collection should also be defined to avoid excessive or ineffective data acquisition and enhance data utilization value.

Data security and privacy protection constitute a non-negotiable baseline and must be institutionalized through strict compliance with relevant laws, regulations, and ethical standards. Measures such as data anonymization, access control, and secure storage should be implemented to prevent data breaches and misuse, thereby safeguarding students' legitimate rights and interests.

Teachers' digital literacy and data interpretation capabilities are critical to the successful implementation of the model. Teachers need competencies in data analysis, AI tool application, stratified instructional design, and targeted intervention. Systematic training, teaching research activities, and practical experience are essential to facilitate the transformation of teachers from knowledge transmitters to data-informed instructional decision-makers and learning facilitators.

The stratified instructional resource system is a core support for model operation. It should be developed in alignment with curriculum standards and professional talent cultivation requirements, forming a well-structured, diverse, and adaptable resource repository, including micro-lectures, courseware, exercises, case studies, and supplementary materials, to meet the needs of learners at different levels.

Furthermore, given the significant differences among institutions in terms of technological infrastructure, faculty capacity, student composition, and disciplinary characteristics, the promotion of this model should adhere to a context-sensitive, institution-specific implementation approach. Rather than adopting uniform templates or simple replication, institutions should tailor processes, tools, and strategies to their specific conditions to ensure feasibility and effectiveness.

6. Conclusions

In the dual context of high-quality development in vocational undergraduate education and digital transformation in education, addressing the tension between learner heterogeneity and standardized instructional provision has become a central task for improving the quality of mathematics teaching. Based on the theories of stratified instruction, adaptive learning, and learning analytics, this study integrates artificial intelligence technologies with the practice of mathematics education in vocational undergraduate contexts to construct an AI-driven stratified adaptive teaching model. It systematically elaborates the model's conceptual connotations, structural framework, functional modules, operational mechanisms, and implementation pathways.

Characterized by data connectivity, adaptive alignment, and developmental enhancement, the proposed model effectively improves instructional precision, process controllability, and learning adaptability, providing both a theoretical reference and a practical framework for the reform of vocational undergraduate mathematics education. However, the model remains at a stage of theoretical construction and preliminary exploration. Its actual instructional effectiveness, scope of applicability, long-term educational value, and optimization pathways require further validation

through multi-institutional, multi-disciplinary, and longitudinal empirical studies.

Future research focus on quantitative evaluation of learning outcomes, optimization of algorithmic models, deeper integration with disciplinary contexts, and cross-course transferability, thereby continuously refining both the theoretical system and practical implementation of the model and promoting the effective application of artificial intelligence in supporting individualized instruction and the cultivation of high-level technical and skilled talents.

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