Reform and Practice of Differentiated Integrated Teaching for College Mathematics Under Emerging Engineering Education

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Abstract: College mathematics serves as a core foundational public course for science, engineering, economics and management majors, which underpins the cultivation of innovative and application-oriented talents within the Emerging Engineering Education framework. Aiming at typical drawbacks in conventional mathematics teaching, including scattered student mathematical foundations, poor compatibility of unified teaching modes, disconnection between theoretical knowledge and professional practice, and simplistic evaluation mechanisms, this study develops a full-cycle differentiated and integrated teaching framework for college mathematics. Guided by individualized instruction theory, constructivism and blended teaching philosophy, the proposed model covers learning status diagnosis, graded content design, multi-level classroom implementation and multi-dimensional assessment. Supported by dynamic hierarchical management, major-oriented modular teaching, online-offline blended instruction and process-based evaluation, a one-year controlled teaching experiment confirms that the optimized model effectively bridges students' academic gaps, enhances their mathematical application capabilities and stimulates learning enthusiasm. This research offers a scientific and feasible reference for curriculum reform and teaching quality improvement of college mathematics in applied undergraduate institutions.

Keywords: College Mathematics; Differentiated Teaching; Emerging Engineering Education; Blended Teaching; Process Evaluation

1. Introduction

Emerging Engineering Education prioritizes interdisciplinary integration, in-depth industry-education integration, competency-based talent training and innovative literacy cultivation, which has reshaped the teaching orientation of basic disciplinary courses. Different from the traditional knowledge-centered indoctrination mode, modern basic course teaching focuses on the integrated development of students' professional competencies and comprehensive literacy. As an essential prerequisite course for science and engineering disciplines, college mathematics not only provides fundamental theoretical support for subsequent professional courses such as college physics, engineering mechanics, signal analysis and econometrics, but also fosters students' rational logical thinking, quantitative analysis awareness and practical problem-solving abilities, forming a core foundational component of the application-oriented innovative talent training system.

In recent years, the diversified enrollment policies of higher education have further widened the individual gaps in freshmen's mathematical foundations. Students with solid secondary school mathematical literacy can quickly adapt to the abstract and systematic knowledge system of college mathematics, whereas numerous students with insufficient foundational knowledge struggle to comprehend core concepts including limits, differentiation and matrices. Rigid unified teaching arrangements fail to cater to personalized and multi-level learning demands, resulting in obvious academic polarization. Underachievers gradually accumulate knowledge deficiencies and develop learning burnout and anxiety, while high-achieving students waste classroom resources on repetitive basic content due to the lack of targeted extended training, which hinders the development of innovative thinking.

Moreover, conventional college mathematics teaching overemphasizes theoretical derivation, formula deduction and mechanical exercises while neglecting practical application, mathematical modeling thinking and knowledge transfer. Most mainstream textbooks are compiled based on disciplinary theoretical logic, lacking scenario-based case design for different

majors. The disconnection between mathematical theories and professional application scenarios leads students to misunderstand mathematics as an abstract, impractical discipline irrelevant to their major development, resulting in vague learning objectives and low learning engagement. Most students are capable of finishing routine exercises mechanically but cannot construct mathematical models to solve practical engineering and real-world problems, which fails to meet the competency standards for emerging engineering innovative talents.

In terms of classroom organization, most public mathematics courses still adopt teacher-dominated cramming teaching with insufficient heuristic and interactive activities. Students are confined to passive shallow learning, and teaching activities mainly target low-order cognitive objectives such as knowledge memorization, comprehension and simple formula application. The shortage of systematic training for high-order abilities including analytical induction, knowledge system construction, knowledge transfer and innovative exploration greatly restricts the cultivation of high-quality innovative engineering talents.

In terms of teaching assessment, most universities adopt a combined evaluation mode of daily performance and final examination, with excessive weight assigned to final summative scores. Daily performance evaluation remains overly simplistic, merely assessing attendance and homework submission without refined evaluation of students' learning process, thinking evolution and individual progress. Accordingly, the diagnostic feedback and incentive functions of teaching evaluation cannot be fully exerted, making it difficult to realize the goal of promoting teaching and learning through assessment.

Combined with the practical teaching dilemmas and talent training requirements of Emerging Engineering Education, this study constructs an optimized differentiated integrated teaching reform system. By refining every link of the teaching process, this research realizes the transformation of college mathematics teaching from standardized unified instruction to personalized, precise and profession-oriented education.

2. Main Problems in Current College Mathematics Teaching

2.1 Obvious Individual Differences in Students' Mathematical Foundations and Poor Adaptability of Unified Teaching

The continuous expansion of college enrollment channels has intensified the stratification of students' mathematical learning bases. Students show significant individual differences in basic knowledge reserve, logical thinking capability and abstract cognitive level. Under unified teaching progress and content arrangements, students with weak foundations struggle to keep up with classroom teaching, resulting in continuous accumulation of knowledge loopholes and gradual loss of learning confidence. In contrast, students with solid foundations lack challenging and exploratory learning tasks, leading to insufficient innovative thinking expansion and low-efficiency utilization of teaching resources. Long-term academic polarization severely restricts the overall improvement of college mathematics teaching quality.

2.2 Backward Curriculum Content and Insufficient Integration with Professional Scenarios

Current mainstream college mathematics textbooks prioritize theoretical integrity and rigorous logical derivation, with few targeted optimizations for differentiated professional training objectives. Engineering, economics and management students adopt identical teaching materials, examples and exercises without adaptive professional scenario design. Engineering majors lack practical training in engineering-oriented scenarios such as differential equation application and numerical computation, while economics and management majors have insufficient practice in statistical inference and optimization decision models. The disconnection between mathematical theories and professional practice greatly limits students' knowledge transfer ability and restricts the cultivation of professional application competencies.

2.3 Rigid Classroom Teaching Mode and Deficient Higher-Order Thinking Cultivation

Most college mathematics classrooms still adhere to the traditional teacher-led teaching mode, leading to monotonous and rigid classroom atmosphere. Teachers spend most class time on knowledge explanation, formula derivation and exercise evaluation, leaving

limited time for students' independent thinking, group collaborative discussion and mathematical modeling practice. After-class tasks are dominated by stereotyped repetitive exercises, with a low proportion of open-ended, comprehensive and practical situational problems. Long-term mechanical exercise training only consolidates students' basic problem-solving skills but fails to cultivate high-order thinking abilities including abstract generalization, logical construction, knowledge migration and innovative exploration.

2.4 Extensive Assessment Mechanism and Inadequate Whole-Process Educational Effect

Over-reliance on final examinations and formalized process assessment are prominent defects in current college mathematics evaluation systems. Daily process assessment is overly simplistic, only covering attendance and homework completion while ignoring key indicators such as classroom participation, error reflection and summarization, phased learning progress and group collaboration performance. Many students adopt last-minute cramming strategies for final assessments, and single final examination results only reflect short-term learning status, failing to record students' long-term learning growth. The imperfect evaluation system weakens the incentive and guiding effects of assessment and hinders the implementation of whole-process educational cultivation.

3. Construction of Differentiated Integrated Teaching System Under Emerging Engineering Education

Based on constructivist learning theory, the individualized teaching concept and progressive competency cultivation principles, this study establishes a four-dimensional integrated differentiated teaching system for college mathematics, covering learning situation diagnosis, modular stratified curriculum design, hierarchical classroom implementation and diversified assessment guidance. The system features progressive logical levels, which realizes precise, professional and personalized talent cultivation adaptable to Emerging Engineering Education requirements.

3.1 Differentiated Learning Situation Diagnosis: Dynamic Hierarchy Adjustment to Avoid Negative Labeling

Accurate learning situation diagnosis serves as the core prerequisite for differentiated teaching implementation. In the first week of each semester, freshman placement tests are conducted to assess secondary school core mathematical knowledge and college mathematics adaptive content. Meanwhile, online questionnaires are distributed to collect students' original learning foundations, learning difficulties, professional orientations and self-improvement demands. Based on comprehensive test data and questionnaire feedback, students are scientifically divided into three dynamic learning tiers: basic, improvement and expansion levels.

To avoid negative psychological hints caused by fixed hierarchical division, a monthly dynamic adjustment mechanism is established. Phased teaching assessments are implemented every four weeks. Combined with students' classroom participation, homework revision quality and autonomous learning performance, their learning tiers are dynamically adjusted. Basic-level students with remarkable progress can be promoted to the improvement tier, and outstanding improvement-level students can advance to the expansion tier. Conversely, students with slack learning attitudes and declining academic performance will be downgraded correspondingly. This mechanism ensures that hierarchical classification acts only as a flexible teaching tool rather than a fixed label for students.

Basic level: This tier focuses on consolidating students' mastery of fundamental mathematical concepts, calculation formulas and operational skills, making up for knowledge deficiencies, meeting basic curriculum requirements, and rebuilding students' mathematical learning confidence.

Improvement level: This tier aims to deepen students' in-depth knowledge comprehension, strengthen logical derivation training and variant exercise practice, help students construct complete and systematic knowledge frameworks, and form stable problem-solving and knowledge application capabilities.

Expansion level: This tier prioritizes the cultivation of students' comprehensive mathematical application ability. By integrating mathematical modeling, data analysis and discipline expansion content, the teaching practice closely aligns with professional innovative training requirements to cultivate students' advanced mathematical literacy.

3.2 Modular Stratified Curriculum Content: Teaching Material Reconstruction for Professional Training Goals

Breaking the inherent chapter constraints of traditional textbooks, this research follows the principles of unified foundational content, differentiated professional cases and progressive ability training, and reconstructs the entire curriculum into three core modules: compulsory foundation module, professional integration module and innovative expansion module.

Compulsory foundation module: Designed for all students, this module covers core knowledge including limit and continuity, derivatives and integrals, vector algebra, matrix operations and basic probability theory. It ensures that all students meet the basic academic standards and guarantees the bottom line of curriculum teaching quality.

Professional integration module: Adaptive teaching cases are developed according to the talent training plans of different majors. For mechanical and civil engineering majors, it focuses on calculus modeling and engineering applications of differential equations; for electrical and automation majors, it highlights matrix transformation and linear equation applications in system analysis; for computer majors, it emphasizes probability statistics, data fitting and discrete thinking training; for economics and management majors, it involves targeted content such as statistical inference, optimization models and risk measurement. This module effectively bridges the disciplinary gap between mathematical theories and professional courses.

Innovative expansion module: Primarily targeting expansion-level students, this module is equipped with mini modeling cases, data analysis practices, open-ended inquiry problems and competition-oriented exercises to fully explore students' innovative potential and practical capabilities.

3.3 Hierarchical Classroom Implementation: Blended Teaching Practice Based on Intelligent Online Platforms

Relying on intelligent teaching platforms including Xuexitong and Yuketang, this study constructs an online-offline interactive hierarchical classroom, realizing full coverage of differentiated teaching design in pre-class preview, in-class instruction and after-class consolidation links.

Pre-class hierarchical preview: Personalized preview resources are precisely pushed according to student tiers. Basic-level students receive conceptual micro-lessons, formula sorting documents and foundational preview exercises; improvement-level students are provided with key and difficult point analysis videos and typical example explanations; expansion-level students are assigned open-ended thinking questions and concise modeling cases, achieving demand-based personalized resource supply.

In-class hierarchical teaching: Core key and difficult knowledge is uniformly explained in class to maintain the integrity of the disciplinary knowledge system. In-class exercises are divided into three gradients: basic proficiency questions, improved variant questions and expanded inquiry questions. Students at different tiers complete corresponding targeted tasks, and classroom questioning and group discussion activities are also hierarchically designed to match the diverse ability levels of all students.

After-class hierarchical consolidation: Differentiated after-class learning tasks are arranged for stratified training. Basic-level students focus on foundational exercises and error sorting and revision; improvement-level students concentrate on variant training and systematic question type summarization; expansion-level students undertake comprehensive application problems and micro modeling tasks. Meanwhile, hierarchical targeted Q&A tutoring is carried out to resolve typical learning problems of students at different levels.

3.4 Diversified Assessment Orientation: Strengthening Process Evaluation to Promote Learning

A three-dimensional comprehensive assessment system integrating process evaluation, phased evaluation and final summative assessment is constructed to optimize the traditional final-exam-dominated evaluation mode. The weight of process evaluation is set at 40%, covering multiple dimensional indicators including classroom participation, hierarchical homework completion quality, error reflection summaries, phased test performance, group collaboration effectiveness and individual learning progress.

Differentiated evaluation criteria are formulated for students at different levels. For basic-level students, evaluation focuses on learning progress to encourage steady improvement; for improvement-level students, it emphasizes the

solidity and proficiency of knowledge mastery; for expansion-level students, it prioritizes the assessment of innovative awareness and comprehensive application capabilities. The diversified evaluation system fully stimulates the learning initiative of students at all levels and realizes whole-process educational cultivation.

4. Teaching Reform Results and Data Analysis

In this teaching reform practice, two parallel Grade 2024 engineering classes of the university were selected as research subjects. The experimental class adopted the proposed differentiated integrated teaching model, while the control class continued to apply the traditional unified teaching mode. A one-year comparative teaching experiment was conducted, and the reform effectiveness was comprehensively evaluated through academic performance statistics, anonymous questionnaire surveys and comprehensive ability tests.

The overall academic performance of the experimental class was significantly improved after the implementation of differentiated integrated teaching. Compared with the control class, the average score increased by 8.6 points, the failure rate dropped by 11.3 percentage points, and the excellent rate rose by 14.7 percentage points. The statistical data verifies that differentiated teaching can effectively assist underachievers in remedying knowledge deficiencies, stabilize the learning outcomes of middle-level students, and improve the comprehensive abilities of high-achieving students, which significantly alleviates the academic polarization phenomenon.

Anonymous questionnaire results demonstrate that the differentiated integrated teaching model can greatly optimize students' learning status and effectively solve prevalent problems including passive classroom learning, separation of theoretical knowledge from professional practice, and insufficient high-order thinking training. Students have achieved comprehensive improvements in learning confidence, classroom participation, knowledge transfer capability and innovative literacy.

Based on one-year in-class teaching practice, the effectiveness of the reform can be summarized in four aspects. First, the dynamic hierarchical management mechanism adapts to individual differences in students' mathematical foundations and solves the unbalanced teaching defects of traditional unified instruction. Second, professional modular teaching bridges the gap between mathematical knowledge and specialized disciplines, clarifying students' learning objectives and boosting learning motivation. Third, online-offline blended hierarchical teaching enriches teaching forms and enhances classroom teaching depth and effectiveness. Fourth, the diversified whole-process assessment system gives full play to the guiding and incentive functions of evaluation, realizing whole-process educational cultivation and comprehensively improving curriculum teaching quality.

5. Reform Reflections and Future Prospects

The differentiated integrated teaching reform proposed in this study has effectively ameliorated the homogenized teaching and theory-practice disconnection problems existing in public mathematics courses. It transforms college mathematics teaching from simple knowledge indoctrination to integrated cultivation of professional competencies and comprehensive literacy, which fits the talent training orientation of application-oriented undergraduate universities under Emerging Engineering Education. Nevertheless, certain deficiencies remain to be optimized in practical implementation. The professional case resource library for different majors requires continuous updating and iteration to keep pace with industrial frontier developments. The data mining and analysis of learning behavior on intelligent teaching platforms needs further improvement to realize more accurate personalized resource pushing. In addition, the integration of mathematical modeling concepts and curriculum ideological and political elements into daily classroom teaching still has great optimization potential.

Future teaching reforms will focus on four core development directions: precision, professionalization, intelligence and literacy orientation. The research team will further optimize hierarchical teaching resources and profession-adaptive case materials, strengthen data-driven learning situation diagnosis, and deepen the integration of curriculum ideological and political education and micro modeling tasks into daily teaching. Meanwhile, the dynamic hierarchical adjustment mechanism and multi-dimensional assessment rules will be continuously improved to construct a more scientific, standardized and replicable precise

teaching model for college mathematics. This research aims to consolidate the mathematical foundation for cultivating innovative and application-oriented talents under the background of Emerging Engineering Education.

6. Conclusion

As an indispensable public basic course in higher education, the teaching quality of college mathematics directly affects the overall talent training level of universities. Against the background of diversified student learning foundations, multi-type professional orientations and continuously upgraded talent training standards, the traditional rigid unified teaching mode can no longer meet the cultivation requirements of emerging engineering innovative talents. Targeting students' individual learning differences, professional training demands and comprehensive ability development rules, this paper constructs a full-process optimized differentiated integrated teaching model covering learning situation diagnosis, curriculum content reconstruction, hierarchical classroom implementation and multi-dimensional assessment. The proposed model effectively solves various practical teaching problems and fully implements the student-centered individualized teaching concept in daily instruction. With strong operability and good adaptability to the teaching reality of local undergraduate colleges, this reform scheme can provide reliable references for curriculum innovation and connotation construction of college mathematics in similar institutions.

References

[1] Jiang T Z, Li S W. An empirical analysis of national teaching achievement awards in mathematics higher education. Journal of Mathematics Education, 2024, 33(3): 71-76.

[2] Zhou Q Y, Meng F J, Shi J. Exploration on public mathematics teaching mode under the construction of first-class application-oriented undergraduate universities. Studies in Advanced Mathematics, 2026(3): 45-49.

[3] Yang Y, Zhang M. Research on the knowledge structure and teaching strategies of Linear Algebra. Studies in Advanced Mathematics, 2025, 28(1): 113-116.

[4] Dong L C, Du W K, Chen X Y. Research on the relationship between college students' growth mindset and mathematical academic performance. Journal of Mathematics Education, 2025, 34(4): 70-77.

[5] Wang P. Research on blended hierarchical teaching reform of advanced mathematics under the background of emerging engineering education. Journal of Higher Education, 2024(18): 145-148.

[6] Liu Y. Practical research on hierarchical teaching of college mathematics based on learning situation analysis. Course Education Research, 2023(32): 89-92.

[7] Zhang L. Analysis on the teaching reform of integrating college mathematics with majors from the perspective of emerging engineering education. Heilongjiang Education (Higher Education Research & Evaluation), 2024(5): 56-58.

