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REFORM AND PRACTICE OF DIFFERENTIATED INSTRUCTION IN ADVANCED MATHEMATICS BASED ON THE STEAM CONCEPT IN THE CONTEXT OF THE NEW COLLEGE ENTRANCE EXAMINATION

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Abstract: The "3+1+2" reform of China's New College Entrance Examination (NCEE) has led to marked differentiation in the mathematical foundations of university freshmen, posing serious challenges to the traditional "one-size-fits-all" model of *Advanced Mathematics* instruction. Taking the undergraduate cohorts of Grade 2024 and 2025 at Northeast Forestry University as research subjects, this paper explores the construction of a differentiated teaching model—encompassing "diagnosis of learning conditions, hierarchical objectives, interdisciplinary integration, and multiple evaluation"—grounded in the STEAM educational concept. Findings indicate that NCEE subject combinations are significantly correlated with university mathematics learning outcomes; interdisciplinary case teaching effectively stimulates learning motivation, and hierarchical teaching strategies narrow the achievement gap among students from different subject-selection backgrounds; and a multiple evaluation mechanism serves as a critical safeguard for the continuous optimization of teaching plans.
Keywords: New college entrance examination; STEAM educational concept; Advanced mathematics; Differentiated instruction; Teaching reform

1 INTRODUCTION

1.1 Structural Changes in Student Intake Caused by the NCEE Reform

In 2019, Heilongjiang Province, as one of the third batch of comprehensive pilot provinces for the NCEE reform, officially implemented the "3+1+2" examination scheme. In addition to the three compulsory subjects—Chinese, Mathematics, and a foreign language—students are required to choose one between Physics and History, and two among Geography, Politics, Biology, and Chemistry, with no further distinction between science and humanities tracks [1]. While expanding students' autonomy in subject selection, this reform has also brought about a significant differentiation in the mathematical preparedness of university enrollees.

An analysis of the final examination results of Advanced Mathematics A2 for the Grade 2025 Vehicle Engineering majors at Northeast Forestry University reveals a clear polarization among the 125 students: the highest score reached 93, while a large proportion of students clustered in the 20–50 range, with the lowest score being 0. A similar pattern is observed among the 98 Computer Science majors. This "cliff-like" distribution is not coincidental but directly reflects the systematic differences in mathematical training received by students with different subject combinations during high school. Students opting for the "Physics + Chemistry + Biology" combination received relatively systematic training in scientific reasoning, while those choosing "History + Geography + Politics" experienced significantly less rigorous mathematical instruction [2].

1.2 The Adaptive Dilemma of the Traditional Teaching Model

For an extended period, the teaching model of Advanced Mathematics has essentially adhered to the paradigm of "unified pace, unified difficulty, and unified assessment" [3]. Prior to the NCEE reform, since the mathematical foundations of the student population were relatively homogeneous, this contradiction was not prominent. However, following the implementation of the "3+1+2" scheme, students in the same classroom may possess vastly different knowledge prerequisites. High school mathematics content encompasses functions, geometry, probability and statistics, among others, corresponding respectively to the three undergraduate courses of Advanced Mathematics, Linear Algebra, and Probability Theory [4]. Students with different subject combinations exhibit varying degrees of mastery over each module. Under the traditional model, well-prepared students perceive the class as insufficiently challenging, while those with weaker foundations develop anxiety and frustration due to their inability to keep pace.

More notably, the NCEE mathematics questions themselves are undergoing transformation, featuring characteristics such as "more thinking, less calculation, anti-routine, and emphasis on essence." In the 2024 joint examination of the three northeastern provinces' prestigious high school alliance, a third-order determinant operation problem appeared, directly involving core concepts of Linear Algebra and blurring the boundary between high school and university mathematics. This evolution necessitates that university mathematics education proactively look downward for articulation.

1.3 The Responsive Potential of the STEAM Concept

STEAM education organically integrates the interdisciplinary knowledge of Science, Technology, Engineering, Arts, and Mathematics. Its core characteristics—interdisciplinary integration, project-based learning, and real-world problem orientation—are intrinsically consistent with the "quality education" orientation promoted in China [5]. Introducing the STEAM concept into Advanced Mathematics instruction holds potential in addressing the differentiation of NCEE student intake in three respects: interdisciplinary integration provides rich contexts for abstract concepts, lowering the threshold for students with different foundations; project-based learning stimulates intrinsic motivation, bridging the confidence gap caused by foundational differences; and diversified evaluation offers equitable assessment opportunities for students starting from different levels (Figure 1).

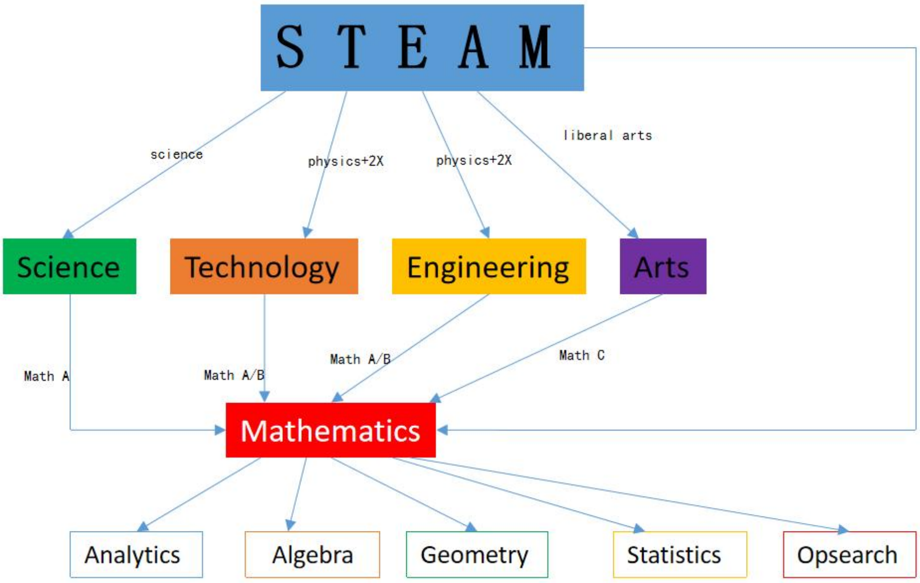

Figure 1 Schematic Diagram of STEAM Education Core Concepts and Interdisciplinary Integration with Advanced Mathematics

2 PRACTICAL EXPLORATION OF THE TEACHING MODEL REFORM

2.1 Diagnosis of Learning Conditions: The Data Foundation of Differentiated Instruction

Following the enrollment of the Grade 2024 freshmen, the project team conducted a questionnaire survey and placement test involving nearly 300 students from three majors: Computer Science, Vehicle Engineering, and Business Administration. The questionnaire encompassed both subjective and objective dimensions. The subjective component included students' perceptions of the differences between high school and university mathematics, their understanding of the application of mathematics in their majors, and their interest in learning. The objective component included NCEE mathematics scores, subject combinations, placement test results, and intended career directions [6].

The survey revealed that students who chose the "Physics + Chemistry" combination scored significantly higher on the placement test than those from other combinations; however, this advantage diverged in the middle of the semester—some high-scoring students declined because they continued to rely on rote problem-drilling strategies, while some students with weaker foundations but appropriate learning methods progressed steadily. Students' perception of the connection between mathematics and their majors directly influenced their learning engagement. Based on these findings, the project team initially classified students into three levels: "extended type" (solid foundation, active thinking), "standard type" (medium level), and "foundation-supplementing type" (weak foundation), with dynamic adjustments implemented throughout the semester.

2.2 Hierarchical Objectives and Interdisciplinary Integration

Regarding hierarchical objectives, the three levels each have distinct emphases. The extended type focuses on cultivating mathematical modeling ability and innovative thinking; the standard type concentrates on deep understanding of core concepts and flexible application of basic methods; the foundation-supplementing type prioritizes filling prerequisite knowledge gaps and building confidence. In classroom instruction, all three levels receive the same core content but are provided with differentiated arrangements in terms of example difficulty, practice gradient, and homework tasks.

Regarding interdisciplinary integration, the project team concretized the STEAM concept into three categories of teaching cases. The first is the "Science + Mathematics" module, which introduces mathematical concepts through physics and chemistry contexts—for example, introducing the calculus of variations through the "brachistochrone problem" and deriving differential equations from radioactive decay models. The second is the "Technology/Engineering + Mathematics" module, which incorporates GeoGebra software for visual teaching and integrates real data from Vehicle Engineering, Computer Science, and other majors—such as using differential equations to model and analyze vehicle suspension systems. The third is the "Arts + Mathematics" module, which demonstrates the aesthetic dimension of mathematics through the golden ratio, fractal geometry, and other examples [7].
Regarding articulation and cohesion, a "Mathematics Articulation Lecture" is organized before the formal course begins, explaining the inherent connections between university and high school mathematics and strategies for transitioning learning methods. For foundation-supplementing students, extracurricular tutorial classes are offered to systematically fill critical prerequisite knowledge gaps in trigonometry and analytic geometry.

2.3 Teaching Process Implementation: Model Application and Dynamic Adjustment

Teaching implementation follows the cyclical process of "pre-class diagnosis—in-class differentiation—after-class consolidation—stage feedback." In the pre-class stage, brief pre-tests are used to assess students' mastery of prerequisite knowledge, enabling the teacher to fine-tune the key points and pace of the lesson accordingly. In the classroom, the teaching process includes eight steps: "topic introduction, knowledge review, problem-driven initiation, scenario creation, inquiry, definition reinforcement, in-class practice, and lesson summary." Among these, "problem-driven initiation" and "scenario creation" are key to embodying the STEAM concept—for Vehicle Engineering majors, the concept of derivatives is introduced through vehicle motion problems; for Computer Science majors, the concept of limits is introduced through algorithm complexity analysis. In-class practice adopts tiered tasks: basic questions are compulsory for all, medium-level questions encourage attempts, and extended questions challenge those who are capable. After-class consolidation adopts a "compulsory + optional" homework system, supplemented by online platforms providing micro-lectures and Q&A support.

2.4 Evaluation System Construction: Multiple Feedback for Continuous Improvement

The project team constructed a tripartite evaluation system consisting of "objective score analysis, process evaluation, and peer review."
Objective score analysis focuses on three aspects: changes in overall score distribution, changes in the achievement gap among students from different subject backgrounds, and individual longitudinal progress. Data indicate that among foundation-supplementing students who consistently participated in articulation lectures and tutorial classes, approximately 35% reached the passing threshold in the final examination, significantly higher than non-participants (approximately 12%). Process evaluation includes dimensions such as class participation, group discussion performance, homework quality, and progress in stage tests, calculated into the final grade to mitigate the inequity of "one examination determining the grade" for students with weaker foundations. Peer review involves organizing teaching observations and collective lesson evaluations each semester, soliciting improvement suggestions from colleagues regarding instructional design, teacher-student interaction, and hierarchical implementation [8].

3 PRACTICAL OUTCOMES, REFLECTIONS, AND PATHS FOR DEEPENING REFORM

3.1 Main Achievements and Limitations

Two years of practice have yielded preliminary results: the proportion of third-level students who are "confident in mathematics" increased from less than 20% at the beginning of the semester to approximately 45%; the achievement gap among students from different subject backgrounds has narrowed to some extent; and project team members have accumulated substantial experience in learning diagnosis, hierarchical design, and interdisciplinary case development.
However, notable limitations persist: the failure rate remains relatively high, indicating that the current intensity of teaching intervention is insufficient to fundamentally reverse some students' learning difficulties; the implementation of the STEAM concept still remains at the level of "case embellishment" rather than achieving comprehensive curriculum restructuring; and the reform's coverage is limited, with a considerable gap remaining before institution-wide institutionalized change can be realized.

3.2 Three Dimensions for Deepening Reform

First, curriculum system reconstruction. Moving from "single-course reform" to "curriculum system reconstruction," articulation courses should be institutionalized. A "Mathematics Articulation Module" (1–2 credits) could be offered during freshman orientation week; within Advanced Mathematics, micro-credit designs based on knowledge modules could allow students with different foundations to choose differentiated learning pathways [9]. Simultaneously, interdisciplinary projects driven by real engineering problems should be developed, enabling the STEAM concept to evolve from "case embellishment" to "curriculum core."

Second, teacher professional development. Differentiated instruction imposes higher demands on teacher competencies. Teachers need not only to master mathematics content but also to understand application scenarios in relevant engineering and technology fields, and to master diagnostic tools and hierarchical instructional design methods. A systematic teacher professional development mechanism should be established, expanding teachers' interdisciplinary perspectives and teaching innovation capabilities through teaching salons, workshops, and other activities [10].
Third, institutional support. Differentiated instruction should be incorporated into the curriculum framework of training programs, multiple evaluation mechanisms should be integrated into academic management systems, and teaching reform outcomes should be included in promotion and performance appraisal systems. Only by transforming reform from "project-based behavior" to "institutionalized behavior," and from "individual exploration" to "organizational action," can the sustained accumulation and broad dissemination of outcomes be ensured.

4 CONCLUSION

The NCEE reform has now entered its eighth year, and the reform of Advanced Mathematics instruction is transitioning from "emergency response" to "systemic reconstruction." This transition is both a practical necessity in response to structural changes in student intake and an inherent requirement for enhancing the quality of undergraduate talent cultivation. The practice presented in this paper demonstrates that diagnosis of learning conditions is the starting point of differentiated instruction, hierarchical objectives are the core, interdisciplinary integration is a means of stimulating motivation, and multiple evaluation is the guarantee for continuous improvement. In the future, concerted efforts across the three dimensions of curriculum system, teacher development, and institutional support are needed to solidify stage-by-stage experience into sustainable teaching systems, ensuring that every student under the NCEE context can achieve their due growth.

COMPETING INTERESTS

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