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Exploration and Practice of Advanced Algebra Curriculum Development in the Context of Emerging Engineering Disciplines: A Case Study of the Data Computing and Applications Program

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Abstract: ***Under the dual background of the New Engineering Education reform and big data technology development, this study explores innovative approaches for cultivating talents in Data Computing. As an emerging interdisciplinary program integrating mathematics, statistics, and computer science, the Data Computing and Applications major requires students to possess solid mathematical foundations and data processing capabilities. Focusing on the teaching reform of Advanced Algebra - a core course of this major, this research proposes three key initiatives: (1) optimizing teaching content through interdisciplinary integration with Analytical Geometry; (2) innovating teaching methodologies by incorporating case-based instruction, mathematical modeling, and flipped classroom approaches; (3) developing specialized textbooks tailored to New Engineering needs. These reform measures aim to cultivate high-quality applied talents meeting the national digital economy development requirements.***

Keywords: New Engineering Education, Data Computing and Applications, Advanced Algebra, Mathematical Modeling.

1. Introduction

Since the Ministry of Education released the "Research and Practice Project Guide for New Engineering Education" in 2017, the development of New Engineering Education pathways in higher education has taken shape. In recent years, numerous studies have emerged regarding discipline-specific curriculum development under the New Engineering framework, including programs such as Detection Guidance and Control Technology [1], Big Data [2], Automation [3], Computer Science [4], Mechanical Engineering [5], and Aerospace-related disciplines [6]. However, as Data Computing and Applications was newly established in 2017, research on its curriculum development remains in the nascent stage.

Against the backdrop of "New Engineering Education" and "Big Data" initiatives, application-oriented engineering institutions must consider how to deeply integrate innovative engineering education concepts to support New Engineering curriculum development and cultivate urgently needed interdisciplinary data computing professionals. The Data Computing and Applications program, rooted in applied sciences including mathematics, statistics, and computer science, differs from traditional theoretical science programs in its focus on talent development. It requires students to establish a theoretical foundation in modern mathematics and statistics, systematically master scientific computing and data processing techniques, and develop the ability to construct mathematical models for practical data challenges while proficiently applying computational methods to solve real-world problems. Consequently, as the most fundamental core course, Advanced Algebra's teaching effectiveness directly impacts both the mathematical literacy of Data Computing and Applications students and their mastery of other core subjects, with lasting implications for their professional development. This necessitates urgent reforms in the teaching philosophy, content, and methodologies of Advanced Algebra courses at application-oriented undergraduate institutions.

As one of the essential core courses for mathematics majors, Advanced Algebra (primarily covering linear algebra) has already yielded some research outcomes in the New Engineering context [8-11]. In 2021, Professor Song Tao pioneered the exploration of Advanced Algebra teaching reforms at application-oriented universities under the New Engineering framework, using the Data Science and Big Data Technology program as a case study [7]. This paper explores and implements reforms in the Advanced Algebra curriculum for the Data Computing and Applications program, focusing on three key aspects: knowledge architecture, pedagogical methodologies, and textbook selection.

2. Key Challenges

2.1 Challenges in Disciplinary Characteristics

The abstract nature of advanced algebra theory leads to teaching content overly focused on theoretical derivation, lacking practical engineering case studies.

2.2 Limitations in Teaching Methodology

Traditional one-way theoretical instruction dominates, with insufficient blended learning approaches, resulting in low student engagement.

2.3 Requirements for Interdisciplinary Integration

The applied science orientation of New Engineering Education demands deep integration of advanced algebra with statistics and computer courses to provide foundational support for subsequent AI/data science core subjects.

3. Reform Plan Design and Problem-Solving Methodology

3.1 Curriculum Content Refinement

3.1.1 Identifying Key Intersections Between Advanced Algebra and Analytic Geometry

Traditionally, most universities offer Advanced Algebra and Analytical Geometry as separate courses to maintain clear mathematical theoretical frameworks. However, problem-solving in Analytical Geometry often requires concepts from Advanced Algebra, while geometric interpretations can significantly enhance students' understanding of abstract algebraic concepts. We propose an integrated approach that strategically combines selected topics from both disciplines to facilitate intuitive comprehension of key concepts. Notable integration points include the relationship between spatial configurations (lines/planes) and determinants and connections between quadratic surface classification and quadratic form standardization.

3.1.2 Mining Ideological and Political Resources from Each Chapter of the Curriculum

We meticulously construct the teaching content framework and delve deeply into the essence of ideological and political education, seamlessly integrating elements such as patriotism, dedication, national sentiment, cultural literacy, and moral cultivation into the teaching process.

For example,

- When teaching polynomial-related content, we intersperse the introduction of concepts and theorems with inspirational stories of scientists to motivate students to explore diligently and engage in in-depth research. By recounting the historical development of polynomial theory, we help students gain a deeper understanding of mathematical discoveries and evolution, as well as the mathematical ideas and methods that emerged during these processes, thereby fostering their mathematical sensibility.

- When discussing determinants, we incorporate the core values of moral education—integrity, rigor, and scientific spirit—by introducing the normative nature of determinants. By combining professional knowledge with moral education elements, we aim to help students profoundly grasp the importance of rigor and seeking truth from facts in scientific methodology, thereby cultivating their scientific thinking.

- In teaching vector algebra, we explore the equation of a line determined by a point on the line and its direction, linking this concept to students' life paths, short-term goals, and long-term aspirations. This approach helps shape their values, inspires patriotic sentiment, and builds confidence in their chosen path.

- When explaining the two-point form of a line equation, we connect it to students' learning experiences, daily lives, and postgraduate entrance exam plans. This aims to cultivate their ability to view the world with a developmental perspective, encourage them to innovate boldly, develop perseverance, and strengthen their determination to strive toward their goals.

3.2 Diversified Teaching Methodologies

To facilitate student' smooth transition from elementary to advanced mathematics and enhance their learning engagement, this pedagogical approach strategically incorporates applied case studies, particularly those demonstrating the interdisciplinary integration of advanced algebra and data computing. These carefully selected practical examples enable students to experience firsthand the satisfaction of applying knowledge to practice, thereby strengthening both their ability and motivation to utilize algebraic concepts in solving real-world problems.

Furthermore, to actively develop students' practical and collaborative skills, we systematically integrate mathematical modeling methodologies into the advanced algebra curriculum. Aligned with the educational objectives of the Data Computing and Applications program, special emphasis is placed on cultivating students' understanding of data modeling principles and techniques. Building upon this foundation, a flipped classroom model will be implemented where student teams collaboratively analyze and solve instructor-proposed problems, followed by structured solution presentations. This innovative approach not only ensures mastery of fundamental theories and methods, but also effectively nurtures students' mathematical reasoning capabilities and technical communication skills.

In teaching practice, particular emphasis is placed on cultivating students' critical thinking and innovative abilities. By designing open-ended questions and project-based tasks, we stimulate students' initiative in exploration and research, enabling them to flexibly apply acquired knowledge to solve complex problems and develop independent problem-solving skills. Furthermore, the course incorporates interactive formats such as collaborative group learning and classroom discussions to facilitate peer exchange and cooperation, thereby fostering teamwork spirit and communication competencies.

Case 1:

This pedagogical case study introduces Chapter 8, "Equations," from The Nine Chapters on the Mathematical Art to demonstrate how ancient Chinese mathematicians employed separated coefficients to represent systems of linear equations—a concept analogous to modern matrix notation. The "direct elimination" method used in solving these systems corresponds to elementary matrix transformations, constituting the world's earliest systematic solution for linear equations. Notably, it was not until the 17th century that Leibniz established a comparable rule in Western mathematics. Integrating this historical context into the curriculum serves to highlight China's mathematical heritage, fostering students' national pride, cultural confidence, and patriotic engagement while enhancing their motivation in learning advanced algebra and analytic geometry.

Case 2:

When discussing surfaces of revolution, this instructional case emphasizes that their geometric properties are determined by both generating lines and directrices. Drawing a parallel to personal development, an individual's decisions and behaviors are similarly shaped by intrinsic character and values. By encouraging students to reflect on their unique traits—akin to selecting distinct generating lines—they recognize the potential to craft diverse life trajectories while maintaining steadfast goals. Just as each point on a generating line adheres to a defined path during rotation, purposeful planning and disciplined action are essential for realizing one's aspirations. This analogy not only deepens comprehension of geometric principles but also cultivates students' self-awareness and goal-oriented mindset.

3.3 Textbook Selection

In compliance with the New Engineering Education framework and applied discipline requirements, this course employs a dual-textbook approach combining David C. Lay's "Linear Algebra and Its Applications" with Lü Lingen and Xu Zidao's "Analytical Geometry". This strategic selection provides comprehensive coverage of both theoretical foundations and practical applications, particularly through Lay's text which features computational case studies in data processing and algorithm design, interdisciplinary applications spanning computer science, statistics, and engineering and problem sets emphasizing real-world data science scenarios.

The textbook combination directly supports the Data Computing and Applications program's mission to develop strong mathematical-statistical foundations, computational thinking abilities and engineering problem-solving competencies.

4. Anticipated Outcomes and Potential for Wider Application

This teaching reform is expected to significantly enhance students' interest and engagement in Advanced Algebra, laying a solid mathematical foundation for cultivating interdisciplinary applied science talents in the Data Computing and Applications program who possess modern mathematical and statistical thinking methods, strong theoretical foundations in natural sciences, and substantial engineering practical abilities. The reform will facilitate breakthroughs in professional competitions, skills contests, and qualification certifications. It effectively meets the training requirements for applied science students by ensuring that through this curriculum, students not only acquire theoretical knowledge in modern mathematics and statistics, but also master techniques and methods for scientific computing and data processing. This enables them to establish mathematical models for various applied data problems and skillfully utilize scientific computing and data processing technologies to solve these practical problems, ultimately developing comprehensive competencies that integrate theoretical understanding with practical application capabilities.

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