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# Teaching Reform and Practice of "Advanced Mathematics" Based on Classification and Hierarchy under the Wave of New Engineering

## —Taking Xinjiang Institute of Engineering as an Example

**Xiujuan Wang, Yongsheng Jiang, Ximin Xing**

School of Mathematics and Physics, Xinjiang Institute of Engineering, Urumqi, China
Email: 1060070466@qq.com

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## Abstract

As a core general compulsory course for engineering majors, the teaching quality of Advanced Mathematics is directly related to the cultivation of students' professional literacy and innovation ability. According to the requirements of education development in the new era and the new talent cultivation plan of our school, it is imperative to deeply promote the teaching reform of Advanced Mathematics. Through a series of innovative measures such as integrating teaching contents, constructing a multiple evaluation system, deeply integrating ideological and political education into courses and innovating teaching methods, this article has successfully realized the organic connection between the Advanced Mathematics course and professional courses, effectively promoted the coordinated development of teaching research and subject competitions, and significantly improved students' mathematical thinking ability and practical application ability, laying a solid mathematical foundation for students' subsequent professional learning and engineering practice.

## Keywords

Advanced Mathematics, Hierarchical and Classified Teaching, Ladder-Type Teaching, Xuexitong Question Bank, Achievement Improvement

## 1. Introduction

The report of the 20th National Congress of the Communist Party of China clearly points out: "Education, science and technology, and talent are the fundamental and strategic supports for the comprehensive construction of a modern socialist

country. We must uphold that science and technology are the primary productive force, talent is the primary resource, and innovation is the primary driving force." Under the strategy of building a strong nation through talent, cultivating the appropriate talent has become the primary task of higher education. Talent development is also the core goal and fundamental mission of universities. Higher mathematics, as a key basic discipline, is of great significance in terms of cultivating students' comprehensive qualities and innovative abilities. In order to meet the requirements of talent cultivation under the background of the new engineering discipline, optimize the teaching content, improve classroom efficiency, make full use of the limited class hours (64 + 80), explore the path of teaching reform in advanced mathematics with full efforts, aim to enhance the teaching quality, meet the learning demands of students of different majors and at different levels, and provide solid support for talent cultivation under the background of the new engineering discipline.

The teaching team of Advanced Mathematics conducted in-depth research on the teaching requirements of Advanced Mathematics from various majors around seven issues such as "the assistance of Advanced Mathematics to professional courses" and "the content that should be added or deleted in the Advanced Mathematics course from the perspective of professional learning". Based on this, Advanced Mathematics was divided into six modules. The research results show that there are differences in the emphasis of requirements for Advanced Mathematics among different colleges (see **Table 1**). Therefore, it is quite necessary to conduct classified teaching of Advanced Mathematics.

**Table 1.** The emphasis of requirements for the content of advanced mathematics in each college.

| Blocks \ Department | Limits and Continuity of Sets and Functions | Calculus of Univariate Functions | Ordinary Differential Equations | Calculus of Multivariate Functions | Vector Algebra and Analytic Geometry in Space | Infinite Series |
|---|---|---|---|---|---|---|
| School of Mechanical and Electrical Engineering | | √ | √ | | √ | √ |
| School of Control Engineering | | √ | √ | | √ | √ |
| School of Energy Engineering | | √ | √ | | √ | √ |
| School of Information Engineering | | √ | | | | √ |
| School of Civil Engineering | | √ | √ | | | √ |
| School of Mining and Geology Engineering | | √ | √ | | | |
| School of Safety Engineering | √ | √ | | √ | | |
| School of Chemical Engineering | | √ | √ | √ | | |
| School of Management Engineering | | √ | | | | |

In recent years, with the continuous expansion of the enrollment scale, the number of students has increased dramatically, and the differences in students' mathematical foundations and learning abilities have become more and more prominent, which has brought severe challenges to the curriculum design and teaching implementation of Advanced Mathematics. In response to this situation, we have implemented stepped teaching. That is, we conduct hierarchical teaching according to the characteristics of students' learning abilities, set different teaching objectives for students with different characteristics, so that students can learn by referring to the objectives during the learning process, making the learning process more relaxed and active, in Zhang & Yan (2023).

## 2. Analysis of the Existing Dilemmas in Teaching under the Background of "New Engineering"

### 2.1. The Mismatch between Teaching Content and Professional Requirements

Students who study Advanced Mathematics come from different majors, and each engineering major has different requirements and emphases on Advanced Mathematics knowledge. However, the update of the teaching model is relatively slow, and the teaching plan has not been adjusted in a timely manner according to the professional requirements. There is an insufficient connection between the teaching content and the practical applications in the majors, and each knowledge module fails to correspond to the actual problems in the majors, causing students to have the feeling that "learning is useless". In addition, classroom teaching overemphasizes the proof of concepts and theorems, which further intensifies the abstractness and complexity of Advanced Mathematics and deepens students' fear of difficulties and the mentality of evasion.

### 2.2. The Teaching Content Does Not Match the Levels of Students

Higher education, as a crucial link in cultivating high-level talents, should give full play to the leading role of students in the classroom, abandon the passive learning mindset of the secondary school stage, and achieve full participation and dominance in classroom practice. However, in actual teaching, it is still mainly characterized by teachers lecturing and students listening, teachers writing on the blackboard and students watching. The teaching content can hardly meet the needs of all students. When the difficulty level of the teaching content is moderate, excellent students may lose their learning interest due to the lack of challenges. Ordinary students can follow the teaching progress, but they are prone to form dependence and it is difficult to cultivate their independent learning abilities. Students with learning difficulties may not understand and keep up with the teaching, gradually developing resistance to mathematics and then staying away from the mathematics classroom, resulting in poor teaching pertinence and the inability to effectively meet the learning needs of students at different levels.

### 2.3. Students' Learning Interests and Participation Levels Are Low

There are numerous knowledge modules in Advanced Mathematics, and the course itself is abstract and complex. The class-hour arrangement for Advanced Mathematics in our university is as follows: 64 class hours for Advanced Mathematics Part 1 and 80 class hours for Advanced Mathematics Part 2. With a tight schedule and heavy tasks, in actual classroom teaching, most of the time is occupied by the teacher's writing on the blackboard and lecturing, leaving little time for students to think and interact. Teachers are unable to promptly answer students' questions and doubts, causing students' problems to pile up. Since knowledge is interconnected, if students fail to understand the previous content, it will have a significant impact on their subsequent learning. Consequently, the learning atmosphere in the classroom becomes dull and dreary. Over time, students may develop resistance, evasion, boredom, and even skip classes or stop listening to the lectures.

How to solve the problem of tight schedules and heavy tasks in Advanced Mathematics classes?

What methods can be used to improve the learning atmosphere in Advanced Mathematics classes?

How can students' interest in learning Advanced Mathematics be stimulated?

### 2.4. The Evaluation Form Is Difficult to Accurately Reflect the Students' Proficiency

Course assessment, as an effective means of evaluating students' learning outcomes, should possess objectivity and comprehensiveness throughout the process. However, the current evaluation model for this course is 60% final exam score is 40% regular performance. The relatively high proportion of the final exam makes teachers and students in the teaching process focus more on problem-solving and scoring. Knowledge explanation emphasizes problem-solving skills, neglecting students' learning conditions in each module. Situations like "testing what has not been learned and not testing what has been learned" are prone to occur, resulting in the inability to objectively evaluate students' true levels. The teaching model of Advanced Mathematics gradually becomes formalized and rigid.

### 2.5. The Integration of Ideological and Political Education into the Curriculum Encounters Obstacles

Advanced Mathematics, as a compulsory public basic course for engineering students, accompanies students for a long time. We expect to organically integrate the knowledge system with ideological and political education, enrich the Advanced Mathematics classroom and make it vivid and interesting. At the same time, we aim to fulfill the fundamental task of fostering virtue through education, cultivate students' mathematical literacy and thinking ability, help them establish correct values and outlook on life, and improve the level of ideological education. However, under the current situation, how to naturally integrate ideological and

political education into the teaching practice remains an urgent problem to be solved.

Against this background, it is particularly urgent to implement the hierarchical and classified reform of the Advanced Mathematics course. This paper, with students as the center, presents the achievements of the teaching reform of the Advanced Mathematics course from aspects such as the implementation of hierarchical teaching, the assistance of information-based teaching, the reform of student assessment methods, and the integration of ideological and political education into the curriculum.

## 3. Innovative and Optimization Measures

### 3.1. Precisely Define the Course Objectives and Optimize the Teaching Content System

Promote the reform of course teaching objectives according to the talent cultivation plan, conduct in-depth cooperation with professional teachers, and implement classified teaching. We divide each major into three categories: mechanical, control, energy, and information are grouped into the mechanical and electrical category; mining, safety, and civil engineering are classified as non-mechanical and electrical categories; and chemical engineering is in a separate category (see **Table 2**).

**Table 2.** Allocation of colleges for classified teaching of advanced mathematics.

| Categories | Involved Colleges |
|---|---|
| Mechanical and Electrical Category | Mechanical, Control, Energy, Information |
| Non-Mechanical and Electrical Category | Mining, Safety, Civil Engineering |
| Chemical Engineering Category | Chemical Engineering |

For mechanical and electrical majors, highlight the application of advanced mathematics in mechanical motion analysis and circuit system modeling. For non-mechanical and electrical majors such as mining and civil engineering, strengthen the mathematical support in engineering structure stability calculation and resource extraction planning. Chemical engineering majors focus on mathematical modeling and optimization in chemical reaction processes. Through joint discussions, precisely screen advanced mathematics knowledge points closely related to the major, build a major-oriented teaching content framework, and enhance students' perception of the "usefulness" of advanced mathematics in their major. Precisely supply teaching content and realize the transformation from "extensive teaching" to "precise education". The theorems, calculations and proofs in advanced mathematics knowledge provide powerful tools for understanding the theories of various disciplines. By summarizing and transforming some professional course knowledge into mathematical problems and conducting teaching

with professional course cases, the classroom content is enriched and the linking role of mathematics is played (see **Table 3**) (Wang, 2019).

**Table 3.** Mathematization of some engineering problems.

| Actual Problems | Disciplines Involved | Mathematical Knowledge Areas Involved |
|---|---|---|
| Velocity (Speed Problems) | Physics | Definition of Derivative |
| Minimum Value Problems in Engineering Accounting | Engineering, Management | Application of Derivative |
| Work Done by Variable Force | Physics | Application of Definite Integral |
| Detection of Cultural Relic Types | Chemistry | Application of Definite Integral |
| Deformation Problems of Cultural Relics | Mechanics | Function Series |
| Calculation of Torque | Machinery | Dot Product and Cross Product of Vectors |
| Trajectory Problems of Transmission Rods | Machinery | Parametric Equations |
| Calculation of Earthwork Volume | Civil Engineering | Definition of Double Integral |
| Heat Transfer Problems | Mining | Differential Equations |

### 3.2. The Promotion of Classified and Hierarchical Teaching Centered on "Students"

In order to implement the concept of "student-centered", adapt to the needs of basic course reform under the application-oriented transformation of the school, and meet the differences in disciplines and students' mathematical foundations, our school has actively explored innovative reforms in the Advanced Mathematics course since 2017. Classified and hierarchical teaching has been carried out in combination with different majors, dividing the teaching content into basic, advanced and extended levels. According to students' college entrance examination mathematics scores, they are divided into A, B and C levels. In September 2024, the hierarchical teaching was changed into A and B levels, in Zhang & Yan (2023).

Class A aims at "mastering the knowledge required by the major and laying a solid foundation for postgraduate entrance examinations and mathematics competitions". It introduces practical application cases and mathematical models of moderate difficulty to cultivate students' ability to apply knowledge to solve practical problems. It also provides in-depth learning resources for students with further improvement needs, such as mathematical principles in artificial intelligence algorithms and mathematical models in big data analysis, to stimulate their learning potential. Class B aims at "mastering the knowledge required by the major and flexibly applying mathematical knowledge in the major". It focuses on the basic

concepts, theorems and basic calculation methods of Advanced Mathematics to ensure that all students master the basic knowledge of the discipline. Practice has proved that hierarchical teaching has selected excellent students for mathematical modeling and mathematics competitions with remarkable results.

### 3.3. Implement a Project-Based and Interactive Learning Model

Design a series of projects based on practical engineering, such as "Analysis and Optimization of Campus Building Energy Consumption" and "Optimization of Machining Process Parameters of Mechanical Parts", and organize teaching driven by projects. Students work in groups and collaboratively apply advanced mathematics knowledge to conduct problem analysis, model construction, solution verification during the project implementation process, cultivating students' team collaboration ability, innovative thinking and practical operation ability, and enabling students to experience the powerful instrumentality of advanced mathematics in solving practical problems. In class, students are required to conduct a whole-process analysis of the project through group discussions and case analysis reports, guiding students to think actively and express their opinions, promoting the collision of ideas and knowledge sharing among students. Through timely feedback and evaluation, students are encouraged to actively participate in classroom interactions, enhancing the classroom learning atmosphere, improving students' learning initiative and attention, and thus achieving an improvement in academic performance.

### 3.4. Deepen the Stepped Teaching Reform and Enhance Students' Application Ability

The study of Advanced Mathematics is a long-term process of accumulation, which needs to follow the principle of gradual progress. First, lay a solid foundation and build a knowledge system, and then pursue techniques and methods. In reality, after one year of studying Advanced Mathematics, students return to their original administrative classes to continue subsequent courses. To achieve the whole-process cultivation and ability improvement of students in Advanced Mathematics, our school has opened elective courses such as "Advanced Mathematics", "Introduction to Mathematical Modeling", "Mathematical Experiment", and "Discrete Mathematics". These courses are based on practical application problems of Advanced Mathematics and use case teaching to guide students to solve problems using mathematical knowledge and software. At the same time, they reserve talents for mathematical modeling competitions and mathematics competitions.

### 3.5. Build an Open Auxiliary Learning Platform to Encourage Students' Exploration and Innovation

In view of the large amount of content in the Advanced Mathematics course and the limited in-class teaching time, we use an open auxiliary learning platform to

extend in-class teaching to after-class, breaking through the limitations of time and space. By using network resources and modern educational technologies, we conduct network-assisted after-class tutoring, cultivate students' awareness and ability of exploratory learning and knowledge application, and promote a virtuous cycle of teaching. The integration of digital technology and mathematics teaching has greatly changed the communication methods among teachers, students and students, and significantly improved students' cooperation ability. Before class, push the chapter teaching and case teaching resources of Advanced Mathematics on platforms such as China MOOC, Xuexi Qiangguo and Bilibili to students; after class, record micro-lectures on the analysis of key and difficult points and the explanation of typical examples according to students' feedback, in Li (2021).

### 3.6. The Scientific Nature of Teaching Evaluation and the Diversification of Implementation Means

Enrich the formative assessment methods. Incorporate students' classroom performance (including participation in discussions, answering questions, team collaboration performance, etc.), the quality of homework completion (emphasizing problem-solving ideas, method innovation and written expression), the results of periodic tests, and after-school learning achievements (such as mathematics reading reports, mathematical modeling practice reports, etc.) into the scope of formative evaluation. Teachers use the Xuexitong platform to create chapter exercises and tests for students of different levels to urge students to review and overcome difficulties.

The final exam is stratified in accordance with the teaching objectives and learning contents of students at different levels. The basic level test paper focuses on the examination of basic knowledge and basic skills to ensure that students master the core knowledge points. The advanced level test paper adds application questions of a certain degree of difficulty on the basis of the basic level to test students' ability to flexibly apply knowledge and achieve accurate assessment of students at different levels. Comprehensively record the students' bit-by-bit progress and comprehensive performance in the learning process, so that the evaluation results can more truly reflect the students' learning state and degree of effort.

### 3.7. Implement the Fundamental Task of "Fostering Virtue Through Education" and Promote the Construction of the Ideological and Political Education Database for Courses

Deeply explore the ideological and political elements in the advanced mathematics knowledge system, such as the exploratory spirit of mathematicians, the dialectical thinking in the development process of mathematical theories, and the social responsibility in mathematical applications (Pei et al., 2024). These ideological and political elements are organically integrated into all aspects of classroom teaching. Through case explanations, classroom discussions, after-school assignments and other forms, students are guided to internalize knowledge into virtues,

qualities and abilities while learning mathematics knowledge. We compile guiding documents such as teaching plans and lesson plans integrating ideological and political education elements from five dimensions: the history of mathematics, philosophical thinking, aesthetic thinking, mathematical thinking and humanistic quality education. A syllabus and teaching materials for case teaching of ideological and political education in courses with chapters as units have been formed, in (Chen, 2023). An ideological and political education group with the teaching and research section as a team has been established. Cases are updated regularly and shared and exchanged (once or twice a month) (**Table 4**).

**Table 4.** Specific cases of ideological and political construction.

| | |
|---|---|
| calculus | Newton and Leibniz in the creation of calculus are introduced |
| derivative | marginal cost and marginal revenue in economics are introduced. |
| limit | the philosophical thought of quantitative change and qualitative change is introduced. |
| integral | working done by a variable force, by transforming the physical problem into a mathematical model and using the definite integral to solve it |

From the long history of the development of mathematics, Through the stories of mathematicians, physical application cases, economic concepts, the philosophical perspective and so on. Students can understand that scientific knowledge is constantly accumulated and evolved. Cultivate students' historical materialist view and make them understand that mathematicians in each era have continuously promoted the development of the discipline on the basis of their predecessors, so as to guide students to cherish the current learning resources and actively contribute to the development of the discipline.

By discussing the safety and energy issues in engineering applications, students can understand the professional ethics and social responsibilities of engineers, and inspire students to uphold a rigorous and responsible attitude in their future careers to ensure the quality of engineering and social interests. Through the combination of the concept of limit and the thought of quantitative change and qualitative change, students are cultivated to view mathematical problems and the changes of all things in the world from the perspective of dialectical materialism.

## 4. The Effectiveness of the Hierarchical Teaching Reform of Advanced Mathematics is Presented

### 4.1. Forge a Characteristic Teaching Syllabus

In the process of teaching reform, teaching syllabi suitable for mechanical and electrical majors and non-mechanical and electrical majors were formulated. For financial management majors, an economic mathematics course was offered. Eventually, the current teaching syllabi of "Advanced Mathematics (Volume 1)

(Volume 2)" were formed.

### 4.2. Construct a Teaching Resource Library

Form various teaching and formative assessment resource libraries. Through the efforts of the course team teachers in the past five years, digital teaching resources that match the students in our school have been created, including "three-stage" teaching resource libraries such as Xuexitong at different levels, homework libraries, and test question libraries, a case library of ideological and political education in courses, and an application case library of Advanced Mathematics that is suitable for classified and hierarchical teaching.

### 4.3. The Teaching Achievements Have Significantly Improved

The achievements of classified and hierarchical teaching have been steadily improved. Through the analysis of the hierarchical teaching achievements of the Advanced Mathematics course in the recent four years, it is found that the Advanced Mathematics achievements of both Level A and Level B classes have been significantly improved (**Table 5** and **Table 6**).

**Table 5.** Scores of advanced mathematics for Level A over the past four years

| Grade | Pass Rate | Excellence Rate |
|---|---|---|
| 2020 | 68% | 18% |
| 2021 | 69% | 22% |
| 2022 | 78% | 27% |
| 2023 | 80% | 30% |

**Table 6.** Scores of advanced mathematics for Level B over the past four years.

| Grade | Pass Rate | Excellence Rate |
|---|---|---|
| 2020 | 62% | 10% |
| 2021 | 74% | 14% |
| 2022 | 86% | 24% |
| 2023 | 88% | 27% |

## 5. Conclusion

The classified and hierarchical teaching practice, which is combined with our school's education and teaching concept of "taking students as the center, aiming at first-class talent cultivation, and using ideological and political integration and information-assisted teaching as means", has achieved remarkable results. This practice not only conforms to the actual situation of our school's running and the cultivation requirements of new engineering, meets the differential needs of students

of different majors and different levels, promotes students' active, autonomous and personalized learning, but also helps teachers teach students in accordance with their aptitudes, optimize classroom organization and effectively solve teaching problems. The hierarchical teaching mode has wide applicability and can provide useful reference and inspiration for teaching innovation in similar colleges and universities.

## Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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