

Research on the Cultivation of Mathematical Modeling Competency in Engineering College Students under Emerging Engineering Education Context

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Abstract

This paper analyzes the internal relationship between emerging engineering education and mathematical modeling ability. By combining the investigation of the current teaching situation in universities, it points out the problems existing in the cultivation of engineering undergraduates' mathematical modeling ability, such as the lagging curriculum system, single teaching method, and weak practical links. It also proposes optimization strategies such as the "three - stage progressive" curriculum system, the "dual - scenario integration" teaching method, and the "three - dimensional support" guarantee mechanism. Finally, taking the reform practice of the mechanical engineering major in a certain university as an example, the effectiveness of the strategies is verified, providing a reference path for the cultivation of mathematical modeling ability under the background of emerging engineering education.

Keywords

Emerging Engineering Education; Mathematical Modeling; Ability Cultivation.

1. Introduction

Since the launch of the Emerging Engineering Education initiative in 2017, it has always aimed at "meeting industrial needs and leading future development", emphasizing the innovative thinking, interdisciplinary integration ability, and engineering practice ability of engineering talents. In emerging fields such as artificial intelligence, new energy, and intelligent manufacturing, the solution of practical problems often depends on the mathematical description and analysis of complex systems-for example, the path planning of unmanned aerial vehicles requires the establishment of an optimization model, and the prediction of the service life of power batteries relies on regression analysis and differential equations. These all highlight the core value of mathematical modeling ability [1]. However, in the traditional cultivation of engineering talents, mathematical modeling is often regarded as an "elective course" or "content exclusive to competitions", and fails to be deeply integrated with professional teaching, making it difficult to meet the cultivation requirements of the Emerging Engineering Education. As an important direction of higher education reform, the Emerging Engineering Education initiative aims to cultivate composite engineering talents who can adapt to the new round of scientific and technological revolution and industrial transformation. As a core literacy connecting mathematical theory and engineering practice, mathematical modeling ability is a key ability for emerging engineering talents to solve complex engineering problems. This research clarifies the positioning of mathematical modeling ability in the cultivation of emerging engineering talents by combing the internal relationship between emerging engineering and mathematical modeling ability, and enriches the relevant theories of "theory - practice" transformation in engineering education. The specific cultivation strategies proposed in this paper can directly provide reference for universities to optimize the teaching of

mathematical modeling, help students transform mathematical knowledge into the ability to solve practical problems, and ultimately contribute to the effective implementation of emerging engineering construction.

This paper adopts the research approach of "status quo research - problem analysis - strategy construction - practical verification". It sorts out the relevant theories of emerging engineering and mathematical modeling through the literature research method; uses the questionnaire survey method (for 500 engineering students from 3 universities) and the interview method (10 professional course teachers) to understand the cultivation status; and combines the case study method, taking the teaching reform of the mechanical engineering major of a certain university as an example, to analyze the implementation effect of the strategy.

2. The Internal Relationship between Emerging Engineering Disciplines and Mathematical Modeling Ability

2.1. The Ability Requirements for Engineering Talents in Emerging Engineering Education

New engineering talents need to possess three core competencies: First, interdisciplinary integration ability. This not only requires mastering the core knowledge of one's own major but also emphasizes the integration ability to break down disciplinary barriers. For example, talents in the artificial intelligence major need to have knowledge of computer algorithms, mathematical modeling, and industry scenarios, and be able to combine machine learning technology with the needs of fields such as medical imaging and intelligent manufacturing. New energy engineering talents need to integrate materials science, power systems, and environmental science to design solutions that balance energy efficiency and environmental protection. This ability is reflected in the ability to quickly identify the connection points of multiple fields when facing complex problems and form innovative solutions through the recombination of cross - disciplinary knowledge. Second, innovative practice ability, focusing on the "from 0 to 1" breakthrough and implementation. It includes both technological innovation, such as developing a new chip architecture to break through the computing power bottleneck, and engineering practice, such as integrating BIM technology and the Internet of Things in intelligent construction to achieve digital control of the entire construction process. At the same time, it requires the ability to predict risks, balance technical feasibility with cost - effectiveness during the innovation process, and ensure that the results can be transformed into actual productive forces. Third, global competence, which includes multi - dimensional qualities: First, an international perspective, being able to gain insights into global scientific and technological front - line trends, such as tracking the international cooperation trends of new energy technologies under the carbon neutrality goal. Second, cross - cultural collaboration, being able to communicate efficiently in transnational R & D projects and coordinate different technical standards and working modes. Third, a sense of responsibility, taking into account sustainable development when participating in global projects, such as integrating the concept of green construction into overseas infrastructure construction and balancing economic benefits with local ecological protection. The common direction of these abilities is to "solve real problems" rather than simply mastering theoretical knowledge.

2.2. The Core Components of Mathematical Modeling Ability

The core components of mathematical modeling ability include three dimensions. The first is the problem transformation ability, which can abstract complex phenomena in practical engineering into mathematical problems. For example, transforming traffic flow regulation into a differential equation model, or refining supply chain optimization into a linear programming problem. This requires accurately capturing key variables and internal logic, and eliminating

secondary interfering factors[2]. The second is the model construction and solution ability. One should not only master methods such as multivariate statistics and numerical analysis, select an appropriate model according to the characteristics of the problem, such as using a neural network to simulate a non - linear system, but also be proficient in using tools such as MATLAB and Python to solve problems. At the same time, one should have the ability to verify the results and optimize model parameters through error analysis. The third is the model interpretation and application ability, which can restore mathematical conclusions to practical solutions. For example, transforming the results of the regression model for water quality monitoring into specific pollution control suggestions, and evaluating the applicability of the model in different scenarios to ensure that theoretical results can effectively guide practice. These three dimensions are interconnected and jointly form a complete closed - loop from reality to theory and then back to reality.

2.3. The Convergence Points Between Emerging Engineering Education and Mathematical Modeling

The "industry orientation" of emerging engineering disciplines is highly consistent with the "problem-driven" nature of mathematical modeling. For example, the optimization problem of the battery management system of new energy vehicles not only belongs to the cutting-edge field of emerging engineering disciplines but also needs to be solved by establishing heat conduction models and charge distribution models, demonstrating the role of mathematical modeling as a "bridge between theory and practice." At the same time, the interdisciplinary knowledge integration involved in the process of mathematical modeling (such as modifying models by combining material science parameters) and the iterative optimization thinking (adjusting model parameters according to experimental data) are also in line with the "innovation and collaboration" emphasized by emerging engineering disciplines.

3. The Current Situation and Problems of Cultivating the Mathematical Modeling Ability of Engineering College Students

3.1. Results of the Current Situation Research

Research shows that there is a significant "disconnect" in the cultivation of the mathematical modeling ability of current engineering undergraduates: In terms of knowledge reserve, 83% of students can proficiently solve calculus and linear algebra problems, but only 32% can transform engineering problems in professional courses into mathematical problems; In terms of teaching content, 70% of the mathematical modeling courses still focus on traditional cases such as "reservoir scheduling" and "population growth", and cases involving new engineering fields such as artificial intelligence and intelligent manufacturing account for less than 10%; In the practical aspect, 65% of students have participated in mathematical modeling competitions, but in daily teaching, only 18% of the courses have set up continuous modeling training programs.

3.2. Analysis of the Main Problems

First, the curriculum system is out of touch with the needs of emerging engineering disciplines. Traditional courses focus on the explanation of mathematical methods and are not linked with professional courses[3]. For example, in the computer major, the courses of "Numerical Analysis" and "Machine Learning" lack modeling connection, resulting in students "learning mathematics but not being able to apply it, and not being able to think of it when encountering problems". Second, the teaching methods are single. 80% of the classrooms still mainly adopt the mode of "teachers explain models and students memorize steps", lacking the inquiry-based links of "raising questions - group modeling - presentation and correction". Students passively accept knowledge and it is difficult for them to form an active modeling awareness. Third, there

are shortcomings in the teaching staff. In the interviews, 60% of the teachers admitted that "they lack engineering practice experience", and can only guide the classic models in the textbooks, and are unable to handle the complex case teaching in the field of emerging engineering disciplines. Fourth, the evaluation mechanism is rigid. The course assessment mostly takes "the correctness of model solution" as the standard (accounting for 75%), ignoring the evaluation of the innovation of the modeling ideas and the rationality of the results, resulting in students "emphasizing calculation and neglecting analysis".

4. Optimization Strategies for the Cultivation of Mathematical Modeling Ability under the Background of Emerging Engineering Education

4.1. Build a "Three - Step Progressive" Curriculum System

The basic level is designed for freshmen and sophomores, offering the compulsory course "Fundamentals of Mathematical Modeling", integrating Python programming and MATLAB tool teaching. It cultivates an interest in modeling through simple cases such as "Campus Express Route Optimization". The advanced level is for juniors, setting up modular courses according to professional directions - for example, the mechanical major offers "Intelligent Manufacturing Modeling", combining cases like "Robot Obstacle Avoidance" and "Production Line Scheduling", integrating methods such as linear programming and graph theory with professional knowledge. The innovation level is for seniors, offering interdisciplinary project courses, collaborating with majors such as computer science and materials. It conducts full - process modeling training around real - world topics such as "New Energy Vehicle Battery Management" and "Intelligent Warehouse System Design".

4.2. Innovate the "Two-Scene Integration" Teaching Method

The classroom scenario adopts the "case-driven - group exploration" model: Starting from typical problems in the new engineering fields (such as "Character Motion Modeling in Metaverse Virtual Scenes"), the teacher guides students to break down the problems (variables: position, time, collision rules; relationships: motion equations, constraint conditions), design models in groups and present them, and finally the teacher gives comments and optimizations. The practical scenario promotes "school-enterprise linkage": Cooperate with enterprises to develop teaching projects. For example, let students participate in the "Component Inventory Optimization" modeling of an automobile enterprise, analyze with real enterprise data, and engineers participate in the whole process of guidance to help students understand that "the rationality of the model needs to conform to the actual production".

4.3. Improve the "Three-Dimensional Support" Guarantee Mechanism

In terms of teaching staff, a dual-teacher team consisting of "university teachers + enterprise engineers" will be formed. University teachers are required to have no less than 6 months of cumulative enterprise practice every three years. At the same time, enterprise technical backbones will be invited to serve as part-time teachers and teach case courses. In terms of the platform, a university-level mathematical modeling laboratory will be built, equipped with industrial simulation software (such as COMSOL, ANSYS) and cloud computing resources to support students in solving and verifying complex models. In terms of evaluation, a "process evaluation + outcome evaluation" approach will be adopted. Process evaluation (60%) focuses on students' innovative thinking and teamwork in the modeling process. Outcome evaluation (40%) emphasizes the engineering application value of the model, and the scores will be given jointly by teachers and enterprise engineers.

4.4. Combining Learning Through Competitions with Daily Teaching

The combination of "promoting learning through competitions" and daily teaching requires the construction of a two-way empowering linkage mechanism. Daily teaching lays the foundation for competitions [4]. Relevant competition cases can be embedded in courses. For example, in the "Data Structure" course, the idea of the optimal solution can be explained by combining with the real questions of algorithm competitions. In the "Engineering Mechanics" experiment, the load analysis requirements of the structural design competition can be introduced, so that basic knowledge points are naturally connected with competition ability points. Competitions, on the other hand, provide a practical verification scenario for daily teaching. Students are encouraged to transform what they have learned in class into competition plans. For example, use calculus knowledge to optimize the path planning of robots. Feedback from competitions can be used to benefit classroom learning and discover knowledge blind spots. At the same time, establish a stepped training system: in the lower grades, simulate competition tasks through course assignments. In the higher grades, form cross - professional competition teams, with teaching teachers serving as instructors. Incorporate competition preparation into practical credits, forming a closed loop of "theoretical learning - competition practice - reflection and improvement - classroom consolidation". This not only avoids the fragmentation of competitions away from teaching, but also makes daily learning more goal - oriented and practical [5].

4.5. Build an Extracurricular Mathematical Modeling Club to Boost the Development of Mathematical Modeling Culture

Make efforts to create the "mathematical modeling culture", with the integration of mathematical modeling ideas into "applying mathematics" as the main line. Adhere to the principles of "strengthening practice, highlighting innovation, and developing individuality", establish an extracurricular mathematical modeling club for students, gradually create an environment for educating students through practice, and enrich and optimize the school's talent cultivation model. The college regularly invites famous teachers and experts to give lectures on mathematical modeling, imparting valuable experience to attract more students to get in touch with mathematical modeling, stimulate students' enthusiasm and initiative in learning mathematical modeling, and enable them to voluntarily participate in mathematical modeling competitions. Set up a special section for mathematical modeling on the college website, and upload resources such as the mathematical modeling teaching plan, relevant courseware, competition questions, excellent papers, and information about mathematical modeling competitions to the website platform, so that more students can conveniently download resources through the mathematical modeling web page and better carry out the learning and training of mathematical modeling [1].

5. Practical Case: Reform Attempts in the Mechanical Engineering Major of a Certain University

Since 2022, a certain university's Mechanical Engineering major has implemented a reform: adding an "Intelligent Warehouse Scheduling Modeling" unit to the "Mechanical Optimal Design" course. Using the real warehouse data of cooperative enterprises as cases, students are required to establish a multi - objective optimization model of "order priority - shortest path - least time". Project - based teaching is adopted, with students divided into groups of 5. Enterprise engineers participate in the guidance once a week, focusing on explaining "how to match model parameters with actual warehouse operations". When evaluating, an "scheme feasibility" indicator (accounting for 30%) is added, and enterprise engineers score the practical application value of the model.

After the reform, the winning rate of students majoring in this field in the mathematical modeling competition increased from 15% in 2021 to 55% in 2023. 85% of the students said that they "can independently transform professional problems into mathematical models". The feedback from enterprises shows that the efficiency of students participating in the project in solving practical problems during internships is 40% higher than that of students under the traditional training model, especially in the "problem - finding - solution - design" stage.

6. Conclusion

Under the background of emerging engineering education, mathematical modeling ability is the core link for engineering talents to transform theoretical knowledge into practical ability. Its cultivation needs to break through the "isolated teaching" mode, and achieve in - depth integration with professional teaching through the coordinated reform of the curriculum system, teaching methods, and guarantee mechanisms. Practice has proven that the "three - stage progressive" curriculum system and the "dual - scenario integration" teaching method can effectively enhance students' modeling awareness and ability, providing strong support for the cultivation of emerging engineering talents.

The cases in this study only involve the mechanical engineering major, and the applicability in other engineering fields (such as electronics and materials) still needs to be verified. In the future, further exploration can be carried out on the combination of artificial intelligence technology and mathematical modeling teaching - for example, using AI tools to automatically generate diverse cases, or simulating complex engineering scenarios through a virtual simulation platform to lower the threshold of modeling practice and make mathematical modeling a "must - have skill" for every engineering student.

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