

Research on Teaching Methods Based on Mathematical Modeling and Their Applications

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Abstract: *Mathematical modeling serves as a crucial bridge between mathematical theory and real-world problems, playing an increasingly important role in education. This paper aims to explore the current state, applications, and future prospects of mathematical modeling teaching methods. Firstly, the article provides an overview of the basic concepts and theoretical foundations of mathematical modeling, introducing the classifications and characteristics of traditional teaching methods and modern teaching methods, including problem-based modeling teaching methods, project-based teaching methods, and computer-assisted modeling teaching methods. Secondly, by analyzing the effectiveness, technical support, and innovations in the application of mathematical modeling teaching methods, the paper reveals the importance of teaching effectiveness, technology application, and innovation. Finally, the paper looks ahead to the challenges faced by mathematical modeling teaching, future development trends, and policy recommendations, offering references for further improving the quality of mathematical modeling education and student capabilities. The research presented in this paper is significant for promoting the innovation and optimization of mathematical modeling education.*

Keywords: *Mathematical modeling, Teaching methods, Effectiveness evaluation, Technology application, Innovative development, Education policy*

Introduction

In the modern educational system, mathematical modeling is receiving increasing attention as an important teaching method. Mathematical modeling not only involves the process of converting complex real-world problems into mathematical problems but also serves as a key approach for cultivating students' abilities to apply mathematical knowledge comprehensively and solve practical problems. With advancements in technology and updates in educational philosophy, mathematical modeling teaching methods continue to evolve and innovate, making research in this area both practically significant and academically valuable. Firstly, mathematical modeling teaching can significantly enhance students' mathematical application abilities and their capacity to solve real-world problems, which is crucial for their future career development and social practice. Secondly, exploring the classifications, effectiveness evaluations, and technology applications of mathematical modeling teaching methods helps identify the strengths and weaknesses in teaching and provides scientific evidence for improving teaching strategies. Lastly, anticipating the future development trends and policy recommendations for mathematical modeling teaching not only offers valuable references for education policymakers and teaching practitioners but also contributes to the ongoing innovation and optimization of mathematical modeling education.

1. Overview of Mathematical Modeling Teaching Methods

1.1 Basic Concepts and Theoretical Foundations of Mathematical Modeling

Mathematical modeling involves the process of transforming complex real-world problems into mathematical forms for analysis and resolution. Its core is to use mathematical tools and methods to abstract, analyze, derive, and predict real-world problems, thereby providing scientific support for decision-making. The basic concepts of mathematical modeling include model construction, model verification and optimization, and model application and interpretation.

In terms of theoretical foundations, the primary theories of mathematical modeling include

Modeling Theory, Optimization Theory, and Numerical Analysis. Modeling Theory focuses on the process of simplifying complex real-world problems into mathematical models, Optimization Theory is concerned with finding optimal solutions within these models, and Numerical Analysis provides the specific algorithms and techniques for solving these models. Additionally, Constructivist Learning Theory and Problem-Based Learning Theory also offer important theoretical support for mathematical modeling teaching, emphasizing that students actively construct knowledge and skills while solving real-world problems^[1].

1.2 Classification of Mathematical Modeling Teaching Methods

Mathematical modeling teaching methods can be categorized based on teaching goals and implementation approaches into several types:

1.2.1 Traditional Teaching Methods

Traditional mathematical modeling teaching typically relies on classroom lectures and textbook learning, with the teacher leading the teaching process and focusing on imparting modeling theories and techniques. Although this method is systematic, it often lacks practicality and innovation, making it challenging to effectively enhance students' actual modeling abilities.

1.2.2 Problem-Based Modeling Teaching Method (PBL)

The Problem-Based Learning (PBL) method involves designing scenarios related to real-world problems to guide students in modeling during the problem-solving process. PBL emphasizes student autonomy and collaboration, effectively improving students' modeling abilities and innovative thinking. The teacher's role shifts to that of a guide and facilitator, assisting students in mastering modeling methods through practice.

1.2.3 Project-Based Modeling Teaching Method (PjBL)

The Project-Based Learning (PjBL) method involves organizing students to complete larger-scale modeling projects, fostering their comprehensive skills and practical experience. The PjBL method focuses on students' modeling practice in real-world environments, enhancing their teamwork and project management skills.

1.2.4 Computer-Assisted Modeling Teaching Method (CATM)

The Computer-Assisted Teaching Method (CATM) utilizes computer software and tools for modeling, such as Matlab and Python for numerical calculations and simulations. The CATM method enhances the efficiency and accuracy of modeling while also developing students' programming skills and data analysis capabilities^[2].

1.3 Teaching Objectives and Strategies for Mathematical Modeling

The core objectives of mathematical modeling teaching are to comprehensively enhance students' modeling abilities, problem-solving skills, and teamwork capabilities. Firstly, through systematic instruction, students should master modeling theories and techniques, enabling them to independently construct and analyze mathematical models to address complex real-world problems. This process requires students not only to understand the fundamental principles of modeling but also to effectively convert theoretical knowledge into practical tools for problem-solving. Secondly, developing students' problem-solving skills is another key objective. Through practical modeling exercises, students will have the opportunity to apply mathematical knowledge to real-life situations, thereby improving their ability to use mathematical tools comprehensively. This ability is crucial for students' future career development.

To achieve these objectives, diverse teaching strategies should be employed to enhance instructional effectiveness. Designing various teaching activities, such as theoretical explanations, case analyses, practical modeling exercises, and project-based practices, can comprehensively improve students' modeling skills. Introducing advanced teaching tools, such as mathematical modeling software, online platforms, and virtual laboratories, can enhance the interactivity and effectiveness of teaching, providing students with a richer learning experience. Additionally, implementing evaluation and feedback mechanisms, through regular assessments of students' modeling outcomes and processes, and offering timely improvement suggestions, helps students continually refine their modeling skills. Furthermore, encouraging autonomous learning and collaboration through group discussions,

cooperative projects, and independent research can stimulate students' initiative and creativity, enhancing their ability to solve real-world problems. The combined use of these strategies not only improves the quality of mathematical modeling teaching but also effectively cultivates the core competencies required in modern society^[3].

2. Application Analysis of Mathematical Modeling Teaching Methods

2.1 Evaluation of the Effectiveness of Mathematical Modeling Teaching Methods

Evaluating the effectiveness of mathematical modeling teaching methods is a critical aspect of assessing the success of teaching practices, and its importance cannot be overlooked. Establishing scientific and systematic evaluation standards and indicators is fundamental for effective assessment. These standards should cover various aspects, including students' modeling abilities, problem-solving skills, and academic achievements, to ensure a comprehensive evaluation of students' overall competencies.

2.1.1 Evaluation Standards and Indicator System

Accurately assessing the effectiveness of mathematical modeling teaching requires the establishment of scientific evaluation standards and an indicator system. These indicators typically include students' performance in modeling competitions, final test scores, and end-of-term project evaluations. Specifically, evaluation standards cover modeling ability (measured by competition awards and project quality), problem-solving ability (assessed through problem-solving in final tests), and academic achievements (such as publication of papers and research results). These evaluations should rely on both quantitative data and qualitative analysis to provide a comprehensive understanding of students' overall capabilities. Quantitative data offers objective assessments, while qualitative analysis reveals thought processes and innovation, resulting in a holistic evaluation of student qualities.

2.1.2 Improvement in Students' Modeling Abilities

Further effectiveness evaluation should focus on the enhancement of students' modeling abilities. To systematically analyze teaching impacts, several evaluation methods can be employed. Firstly, comparing test scores before and after instruction can measure improvements in students' knowledge and skills. Secondly, using modeling ability assessment scales can provide a comprehensive evaluation of students' capabilities and progress during the modeling process. Additionally, assessing students' performance in real-world projects can shed light on the impact of teaching on problem-solving abilities and innovative thinking. These methods combined offer comprehensive data support for optimizing teaching strategies.

2.1.3 Evaluation of Teaching Effectiveness

Evaluating teaching effectiveness is crucial in mathematical modeling instruction. The evaluation should consider several aspects: firstly, testing the effectiveness of teaching methods in different environments; secondly, ensuring that teaching content comprehensively covers key knowledge and skills; and thirdly, examining how teachers respond to student feedback and implement improvements. Combining these evaluations provides data support for adjusting teaching methods, identifying shortcomings, and optimizing instruction. Thus, effectiveness evaluation should include scientific standards, a focus on improvements in student capabilities, and an assessment of teaching effectiveness to fully understand teaching outcomes and support enhancements.

2.2 Technological Applications and Support in Mathematical Modeling Teaching

In mathematical modeling teaching, technological applications and support have increasingly become key factors in advancing instructional progress. The following is a detailed exploration of several aspects of technological applications:

2.2.1 Application of Mathematical Modeling Software

Mathematical modeling software significantly enhances the efficiency and accuracy of the modeling process. Tools such as Matlab and Python offer powerful computational and data analysis capabilities, allowing students to achieve higher precision and faster processing speeds when constructing, optimizing, and validating complex models. Matlab's matrix operations and simulation features, along with Python's extensive libraries (such as NumPy, SciPy, Pandas, and Scikit-Learn),

enable students to handle large datasets, execute complex algorithms, and conduct in-depth model analysis. The effective use of these tools not only improves students' practical skills but also deepens their understanding of modeling theories and practices, thereby enhancing their ability to apply mathematical models in real-world scenarios^[4].

2.2.2 Integration of Online Platforms and Virtual Laboratories

The integration of online platforms and virtual laboratories provides a more flexible and interactive learning environment for mathematical modeling teaching. Platforms such as Khan Academy, Coursera, and edX offer a wealth of modeling courses and real-time discussion features, supporting students in online knowledge acquisition and technical communication. Virtual laboratories provide an intuitive learning experience through simulated experiments and virtual modeling practices. By using virtual laboratories, students can simulate complex system dynamics in a controlled and safe environment, conduct multiple experiments and adjustments, and gain a deeper understanding of various factors in the modeling process. This technological support enhances the interactivity of teaching and student engagement, enabling students to practice modeling in scenarios that closely resemble real-world conditions, thereby improving their problem-solving and innovative thinking abilities.

2.2.3 Application of Cloud Computing and Remote Collaboration

Cloud computing-based collaboration platforms have brought new changes to mathematical modeling teaching. These platforms allow students to collaborate in real-time from different geographical locations, engage in collective modeling and data analysis. This remote collaboration mode broadens students' cooperative perspectives, fosters interdisciplinary teamwork, and develops their comprehensive and cross-cultural communication skills. For example, by using cloud computing platforms, students can share data, synchronize work progress, and discuss solutions in real-time with team members from different regions. This mode not only enhances students' collaboration skills but also improves their ability to integrate interdisciplinary knowledge^[5].

2.2.4 Application of Big Data Technology

The introduction of big data technology provides a new dimension to mathematical modeling teaching, enabling students to handle and analyze larger datasets. These technologies allow students to explore and verify the performance of models in the context of big data, improving the accuracy and applicability of models. By leveraging big data technology, students can gain valuable insights when analyzing vast amounts of data, further optimizing modeling strategies and prediction accuracy. This technological application enriches the teaching content and provides new opportunities for enhancing students' practical application skills.

In summary, technological applications and support in mathematical modeling teaching not only improve the efficiency and accuracy of the modeling process but also offer students a richer and more flexible learning experience. Through the effective use of mathematical modeling software, the integration of online platforms and virtual laboratories, the application of cloud computing and remote collaboration, and the introduction of big data technology, these innovative technologies lay a solid foundation for the future development of mathematical modeling teaching and provide strong support for students in solving complex problems and practical applications.

2.3 Technological Applications and Innovations in Mathematical Modeling Teaching

The application and innovation of technology have brought significant transformations to mathematical modeling teaching. Recently, the introduction of big data analysis technology and artificial intelligence (AI) has provided new possibilities for modeling education. Big data analysis technology can handle and analyze vast amounts of data, assisting students in deep data mining and pattern recognition during actual modeling tasks, thereby enhancing the predictive capabilities and application range of models. Artificial intelligence technology, especially machine learning and deep learning algorithms, can automatically optimize model parameters during the modeling process, improving the accuracy and efficiency of models.

Additionally, the application of mixed reality technologies, such as augmented reality (AR) and virtual reality (VR), in modeling teaching has also shown tremendous potential. These technologies offer students an immersive learning experience by visualizing and simulating the modeling process, helping students understand complex concepts and system dynamics more intuitively. Innovative technological applications not only enhance the engagement and interactivity of teaching but also significantly expand the boundaries of modeling education, providing students with richer learning

resources and practical opportunities.

In summary, the application analysis of mathematical modeling teaching methods requires not only a systematic evaluation of their effectiveness but also an in-depth exploration of technological support and innovation in teaching. These factors, working together, provide strong support for optimizing teaching strategies and improving teaching quality.

3. Future Perspectives on Mathematical Modeling Teaching Methods

3.1 Innovative Development Trends in Mathematical Modeling Teaching Methods

Innovation will be a key driver in the future development of mathematical modeling teaching methods. Firstly, intelligent teaching is an important trend. The application of artificial intelligence and machine learning technologies will facilitate the development of intelligent tutoring systems. These systems can automatically adjust teaching content and methods based on students' performance and needs, providing a personalized learning experience.

Secondly, interdisciplinary integration will also drive innovation in mathematical modeling teaching. By integrating with disciplines such as data science, engineering technology, and economic management, mathematical modeling teaching will place greater emphasis on practical applications and the development of comprehensive skills. This interdisciplinary integration will not only enhance students' ability to solve real-world problems but also foster their cross-disciplinary innovative thinking^[6].

Additionally, the application of virtual reality (VR) and augmented reality (AR) technologies will bring new transformations to mathematical modeling teaching. Through these technologies, students will be able to conduct modeling experiments and simulations in virtual environments, gaining an intuitive understanding of complex mathematical models and system dynamics. This immersive learning experience will greatly enhance students' motivation and modeling capabilities.

3.2 Future Directions and Policy Recommendations for Mathematical Modeling Teaching

Looking ahead, mathematical modeling teaching should focus on the following directions and develop corresponding policy recommendations to promote its advancement.

3.2.1 Strengthening Educational Resources and Technological Support

Government and educational departments should increase investment in resources for mathematical modeling teaching, promoting the adoption of modern teaching tools and software. Additionally, support for teacher training should be provided to enhance educators' professional capabilities and technological application skills in modeling teaching.

3.2.2 Promoting Interdisciplinary Collaboration and Innovative Educational Models

Educational institutions should encourage the integration of mathematical modeling teaching with other disciplines, developing comprehensive teaching projects and curricula to cultivate students' comprehensive and practical skills. Furthermore, promoting innovative educational models such as project-based learning and problem-based learning can further improve students' practical abilities and innovative awareness.

3.2.3 Establishing Clear Policies and Evaluation Mechanisms

A policy framework and evaluation standards specifically for mathematical modeling teaching should be established. Regular assessments of teaching effectiveness and innovative practices should be conducted, with timely adjustments and optimizations to teaching strategies. These policies should not only focus on teaching quality but also address students' learning needs and societal demands to ensure the continuous development and optimization of mathematical modeling teaching.

By implementing these directions and policy recommendations, the innovation and development of mathematical modeling teaching can be further advanced, laying a solid foundation for cultivating students with high-level modeling skills and comprehensive qualities.

Conclusion

Mathematical modeling teaching methods have demonstrated extensive application prospects in educational practice, but they also face challenges such as insufficient resources, limited technical support, inadequate teacher professional development, and variations in students' mathematical foundations. Addressing these challenges effectively requires innovation and the application of technology. The introduction of intelligent teaching, interdisciplinary integration, and technologies such as virtual reality (VR) and augmented reality (AR) will bring significant changes and opportunities to mathematical modeling teaching.

Future development should focus on several key areas: Firstly, enhancing the construction of educational resources and technical support, improving teacher training levels, and increasing the adoption of modern teaching tools. Secondly, promoting interdisciplinary collaboration and innovative educational models, such as project-based learning and problem-based learning, to enhance students' practical abilities and comprehensive qualities. Lastly, establishing clear policy frameworks and evaluation mechanisms, regularly assessing teaching effectiveness and optimizing teaching strategies, to ensure the continuous improvement of teaching quality and student capabilities.

Implementing these measures will not only improve the quality of mathematical modeling teaching but also lay a solid foundation for students' future career development, while providing valuable references for further exploration and optimization of mathematical modeling teaching methods.

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