Journal of Education and Culture Studies
ISSN 2573-0401 (Print) ISSN 2573-041X (Online)
Vol. 9, No. 2, 2025
www.scholink.org/ojs/index.php/jecs

Original Paper

Research on Innovative Teaching Models for Advanced Mathematics Integrating STEM Education Concepts and Mathematical Modeling Ideas

Feng Zhao & Xiaoye Ding

General Education Department, Anhui Xinhua University, Hefei 230088, Anhui, China

Abstract

This paper addresses the issues of abstract content and dry teaching methods in higher mathematics that are disconnected from practical application by proposing an innovative teaching model that integrates STEM education concepts with mathematical modeling ideas. This model redesigns the teaching content and process through interdisciplinary integration and innovative practice, emphasizing the enhancement of student agency and practical abilities. Implementation strategies include developing case-driven teaching modules, adopting project-based learning, and introducing computer-assisted tools. The systematically constructed teaching model can effectively improve students' enthusiasm for learning, autonomy, and their ability to apply and innovate in mathematics. This model provides a new direction for scientific and systematic reform in higher mathematics education.

Keywords

STEM education, mathematical modeling, higher mathematics, teaching reform, innovation ability

1. Overview of the Educational Concept of STEM and the Idea of Mathematical Modeling

1.1 STEM Educational Concept

STEM, an acronym for Science, Technology, Engineering, and Mathematics, represents the integration of these four disciplines. The core concept of STEM education is interdisciplinary integration and practical application, aimed at cultivating students' abilities to solve real-world problems. STEM education emphasizes the combination of theory and practice, encouraging students to explore and apply knowledge through project-driven learning, teamwork, and hands-on operations. This educational model is designed to stimulate students' enthusiasm for learning and enhance their comprehensive abilities, particularly in innovative thinking, logical reasoning, and abstract thinking.

The STEM education model is fundamentally grounded in the comprehension of core disciplinary concepts, with a strong emphasis on interdisciplinary integration. As illustrated in Table 1, each of

these four core disciplines has distinct objectives that can be incorporated into the teaching process through situational, task-driven, or inquiry-based methodologies to achieve cross-disciplinary synthesis. This educational approach aims to foster students' comprehensive literacy, empowering them to apply multidisciplinary knowledge and skills when addressing real-world challenges.

Table 1. Framework of the STEM Educational Concept

Core Area	Specific Goals	The approach of interdisciplinary integration
Science	Cultivate the spirit of inquiry and experimental skills	➢ Scenario-based: Achieved through real-life scenario simulation. ➢ Task-driven: Achieved by completing specific tasks ➢ Inquiry-based: Achieved through independent exploration and research
Technology	Develop innovative thinking and application skills.	
Engineering	Strengthen design reasoning and data analysis capabilities	
Mathematics	Enhance logical reasoning and data analysis skills.	

1.2 Mathematical Modeling Idea

Mathematical modeling is a methodological approach that addresses real-world problems by developing mathematical representations. It involves abstracting and analyzing these problems, translating them into mathematical language to leverage mathematical tools for solutions. The primary objectives of mathematical modeling are to grasp the essence of the problem, forecast future trends, optimize decision-making processes, and innovate control mechanisms. This approach underscores the importance of starting with real-world issues and applying mathematical techniques for analysis and resolution. Successful mathematical modeling requires not only a strong foundation in mathematics but also an in-depth understanding of the subject matter, along with the ability to integrate mathematical solutions with practical contexts.

1.3 Integration of "STEM Educational Concept and Mathematical Modeling Idea"

STEM education emphasizes the cross-disciplinary integration of science, technology, engineering, and mathematics. Mathematical modeling serves as a bridge that applies mathematical theory to solve practical problems, aligning with the core concept of STEM education.

Firstly, both STEM education and mathematical modeling emphasize the cultivation of interdisciplinary abilities. STEM education advocates for the deep integration of science, technology, engineering, and mathematics to nurture students' innovative spirit and practical skills through interdisciplinary integrated learning. Similarly, mathematical modeling requires students to combine mathematical knowledge with insights from other disciplines to solve real-world problems. This

interdisciplinary approach helps students develop a holistic personality and an integrated knowledge system.

Secondly, both emphasize practical operations and problem-solving. STEM education fosters learning through project-driven and problem-solving approaches, enabling students to apply theoretical knowledge to real-world situations. Mathematical modeling begins with actual problems from the real world, addressing them by creating and solving mathematical models, which necessitates a strong grasp of mathematical concepts and their application in specific contexts.

Furthermore, both STEM education and mathematical modeling promote deep learning among students. STEM education enhances students' ability to handle complex information, perform intricate modeling, and carry out detailed calculations through the integration of modern technology, thereby facilitating deep learning. Mathematical modeling enables students to deeply understand mathematical concepts by applying abstract ideas to specific problems, thus encouraging deep learning.

Lastly, the integration of these two approaches helps cultivate students' innovative spirit and lifelong learning abilities. In the combination of STEM education and mathematical modeling, students not only acquire knowledge and skills but also learn how to learn and innovate, which is invaluable for their future academic and career development.

Briefly, the organic integration of STEM educational principles and mathematical modeling fosters a deeper comprehension and application of mathematical knowledge among students, while also invigorating their innovative mindset.

2. The Significance of Integrating "STEM Education Concepts + Mathematical Modeling Ideas" into Advanced Mathematics

The teaching of advanced mathematics, a critical domain for fostering mathematical literacy, logical thinking, and innovation skills, is currently challenged by the disconnect between traditional pedagogical methods and contemporary educational demands. Incorporating STEM education principles and modeling concepts, which integrate advanced mathematics with other disciplines, not only enhances the curriculum's practicality and innovation but also comprehensively improves students' academic qualities.

2.1 Optimization of Advanced Mathematics Classroom Structure

The content of advanced mathematics is characterized by its abstract nature, making the teaching of calculus theory often dry and monotonous. The singular teaching method dulls the classroom atmosphere. Coupled with students' feelings of "learning without understanding, learning without application," advanced mathematics teaching finds itself in a dilemma. By integrating STEM education concepts and modeling ideas into advanced mathematics courses, we can transform abstract concepts into concrete ones and complex problems into simpler ones. Actual scientific and engineering issues are visually demonstrated using mathematical models, and students are encouraged to use computer-assisted tools to further solve these problems. This approach not only helps students

understand the application of mathematics in solving practical problems but also deepens their comprehension and mastery of the subject matter. Additionally, it enhances students' autonomy and innovative abilities.

2.2 Enhancement of Teachers' Knowledge Reserve and Teaching Research Ability

The integration of STEM education concepts and modeling necessitates that teachers possess interdisciplinary knowledge, practical problem-solving skills, innovative teaching strategies, technological proficiency, teamwork, a commitment to continuous learning, diverse assessment methods, and cultural and ethical awareness. These competencies are essential for effectively guiding students in exploring science, technology, engineering, and mathematics (STEM) fields, enhancing their comprehensive qualities, and laying a solid foundation for their future academic and career development. Consequently, this fosters the effective improvement of college mathematics teaching quality.

2.3 Adaptation to the Needs of Talent Cultivation in the New Era

In the new era, there is an urgent demand for innovative talents. Consequently, the teaching of advanced mathematics courses is undergoing profound reforms. Against this backdrop, the organic integration of STEM education concepts and mathematical modeling ideas into the curriculum system is particularly important. This teaching model not only integrates knowledge across disciplines but also emphasizes inquiry-based learning driven by problem-solving. It enables students to deepen their understanding and application of mathematical theory through solving practical problems. Such teaching strategies help cultivate critical thinking, innovative ability, and team spirit—qualities essential for high-quality talents in the new era. Therefore, advanced mathematics teaching that incorporates STEM education concepts and mathematical modeling ideas aligns more closely with current education reform directions and aids in cultivating compound talents suited for future societal development.

3. Teaching Design Approach Integrating "STEM Education Concepts + Mathematical Modeling Ideas" into Advanced Mathematics

This teaching model transcends the conventional classroom's simplistic knowledge transfer, focusing instead on the application of knowledge through problem-solving and thereby enhancing students' capabilities. It consistently reflects on and refines teaching practices, aiming to innovate and optimize educational outcomes.

As illustrated in Figure 1, the teaching design approach for advanced mathematics, grounded in "STEM Education Concepts + Mathematical Modeling Ideas," is structured into four main steps. The first step involves designing learning objectives centered around problems. By using specific scientific and engineering problems as entry points, students' interest in learning is stimulated. This phase corresponds to the question-posing stage of mathematical modeling, highlighting that mathematics is not an isolated discipline but closely linked to the real world, embodying the interdisciplinary

integration characteristic of STEM education. The second step consists of group discussions, in-depth analyses, and exploration of the problem's essence. Here, students delve into the practical problems introduced in the previous step to uncover their mathematical implications. This stage represents the problem analysis phase in mathematical modeling. Through case discussions and teamwork, this process cultivates communication and collaboration skills, enhances problem-solving abilities, and sharpens logical and critical thinking skills. The third step introduces mathematical concepts and constructs corresponding models. Students employ mathematical thinking methods such as observation, induction, and abstraction to distill the core mathematical issues from complex scientific and engineering contexts, transforming them into appropriate mathematical models. This phase nurtures students' ability to apply mathematical knowledge. The fourth step focuses on problem-solving, evaluation, and dissemination of conclusions. After mastering basic calculation methods, students are encouraged to use mathematical software like MATLAB or Python to solve and analyze models, thereby strengthening their proficiency with mathematical tools. This step embodies the "learning by doing" principle of STEM education, emphasizing hands-on experience and practical application. Students revisit the original problem, evaluate the results of their mathematical models, assess their effectiveness and limitations, and suggest improvements. Additionally, they explore applying solutions to analogous problems or extending them to other fields, considering the potential deficiencies or advancements in relevant mathematical theories. This final step aims to foster students' ability to draw generalizations from specific instances and stimulate innovative thinking, aligning with the innovation emphasis of STEM education. Framework of Teaching Design Approach Based on "STEM Education Concepts + Mathematical Modeling Ideas" for Advanced Mathematics.

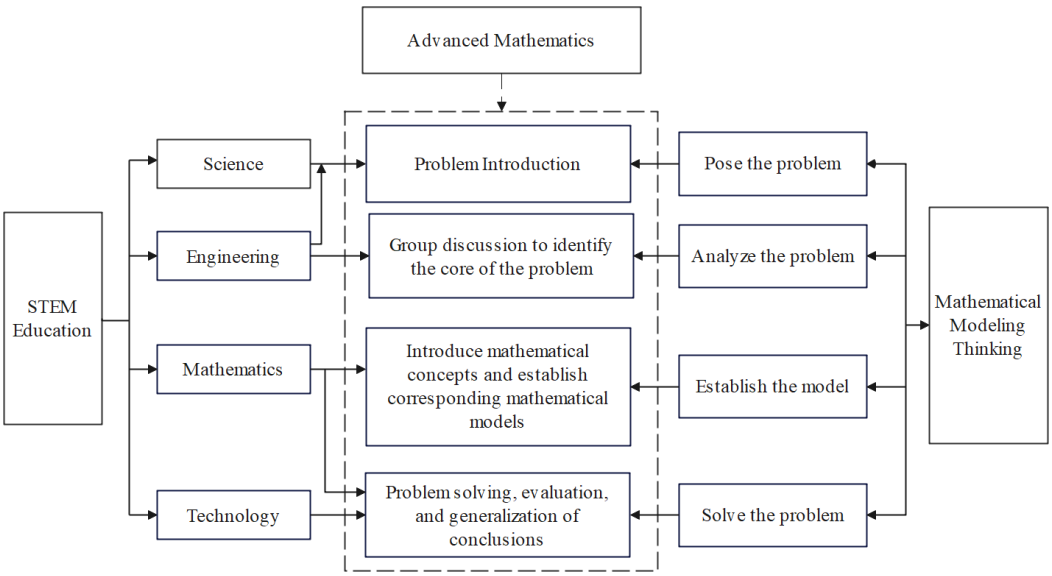

Figure 1. Framework of Advanced Mathematics Instructional Design Based on "STEM Education Concept + Mathematical Modeling Thinking"

This four-step teaching method not only enriches students' mathematical knowledge but also cultivates practical skills, teamwork, problem-solving abilities, and innovative consciousness. Such a teaching model effectively prepares students for a future technology-driven society and lays a solid foundation for their comprehensive development. Combining STEM education concepts with mathematical modeling ideas, this teaching model deepens students' understanding of mathematical concepts and methods while equipping them with a comprehensive toolkit to address real-world complexities, preparing them to become innovative talents in interdisciplinary fields.

The integration of "STEM Education Concepts + Mathematical Modeling Ideas" into advanced mathematics teaching is exemplified through the concept and computation of double integrals (Table 2). This specific implementation case demonstrates how these interdisciplinary elements can be seamlessly incorporated into classroom instruction.

Table 2. Example of Integrating "STEM Education Concepts + Mathematical Modeling Ideas" into Classroom Teaching

STEM Education Concepts + Mathematical Modeling Ideas	Taking Double Integrals as an Example
Problem Introduction	Introduce the concept of double integrals from an engineering problem, proposing the practical problem of "how to calculate the mass of a plane slice with non-uniform material distribution."
Group Discussion, Finding the Core of the Problem	Transform the non-uniform slice into the mass calculation of a uniform slice
Introducing Mathematical Concepts, Establishing Corresponding Mathematical Models	Use the mathematical method of "division - approximation - summation - taking limits," introduce the definition of double integrals, and establish a mathematical model for calculating the mass of a non-uniform plane slice
Problem Solving, Evaluating and Promoting Conclusions	Provide the calculation method of double integrals, encourage students to calculate the mass of the given slice by hand or programming, and then further consider how to solve the mass of a spatial geometric body with uneven density

4. Integrating "STEM Education Concepts + Mathematical Modeling Ideas" into the Teaching Improvement of Advanced Mathematics

By integrating the principles of STEM education and embedding mathematical modeling methodologies into advanced mathematics courses, the teaching process is meticulously designed as an interactive continuum of model construction, identification, and application. This approach enhances

student engagement by clearly articulating concepts, deepening understanding, and applying knowledge across various contexts. It emphasizes a profound comprehension and mastery of content while cultivating students' ability to develop and refine mathematical thinking methods. Through modeling activities, students intuitively grasp concepts, reinforce learning through practical operations, and further enhance their understanding and skills through application, making conceptual learning more intuitive and engaging.

To effectively incorporate the "STEM Education Concept + Mathematical Modeling Thinking" into advanced mathematics instruction, adjustments and optimizations at multiple levels are essential.

4.1 Update of Teaching Content

In teaching advanced mathematics, it is essential to ensure that students have a solid mathematical foundation and enhanced mathematical literacy. Additionally, the curriculum should integrate mathematical knowledge with practical problem-solving skills. Teaching should aim to cultivate interdisciplinary thinking and overall student qualities while stimulating innovation and critical thinking. Therefore, when preparing lessons, teachers should seek out relevant disciplinary problems and mathematical models related to advanced mathematics. These models should be comprehensible, and the disciplinary knowledge should be independent, complete, and simple to understand, ideally sparking students' curiosity. For example, while teaching the concept of "function maxima and minima," we can introduce practical application scenarios such as "advertising category investment problems" and "courier distribution problems," allowing students to analyze and solve these problems by establishing mathematical models. When discussing the "Zero Point Theorem," questions like "Can a chair be stabilized on an uneven surface?" can guide students in exploring and verifying mathematical principles. While covering "differential equations," introducing models such as "radioactive element decay" helps students understand the practical applications of differential equations in physics and engineering fields. Through such teaching methods, we not only help students consolidate and expand their mathematical knowledge but also cultivate their ability to apply mathematics to solve real-world problems. This combination of theory and practice in teaching helps stimulate students' interest in learning, improves their comprehensive qualities, and lays a solid foundation for their future development in various disciplinary fields.

4.2 Improvement of Teaching Design and Methods

To effectively integrate the "STEM Education Concept + Mathematical Modeling Thinking" into teaching, it is essential to innovate and improve traditional pedagogical models and methods. Designing problem-centered course modules and project tasks encourages students to engage in inquiry-based learning through specific challenges. Employing teaching strategies such as Project-Driven Learning (PDL) and Problem-Based Learning (PBL) stimulates students' enthusiasm for active learning and problem-solving (Wang Youwen, Gao Zhenguo, & Liu Taofeng, 2022). Additionally, group collaborative learning and discussions not only strengthen the spirit of teamwork among students but also enhance their social skills. The use of case studies and hands-on practice

increases the interactivity and enjoyment of learning, making students more engaged. Moreover, fully utilizing modern information technology tools, such as mathematical software and online learning platforms, can further enhance the interactivity and flexibility of teaching.

4.3 Innovation of Evaluation Mechanism

To complement innovative teaching methods, it is essential to design a scientifically sound evaluation mechanism. Guided by the philosophy of STEM education and mathematical modeling, we prioritize not only the final outcomes of learning but also the cultivation of students' abilities and knowledge acquisition during the learning process. Therefore, an innovative evaluation system should integrate formative and summative assessments to comprehensively measure students' learning progress.

The content of evaluation should be diversified, The content of evaluation should be diversified, en quality, report writing ability, encompassing model construction quality, report writing ability, oral presentation skills, and communication abilities. Additionally, incorporating self-evaluation and peer evaluation can stimulate deep reflection on learning processes, promote autonomous learning, and encourage mutual cooperation, thereby deepening knowledge understanding and application. This evaluation mechanism enables a more accurate assessment of students' learning status while motivating them to make continuous progress in their educational journey.

4.4 Continuous Feedback and Iteration

Integrating the "STEM Education Concept and Modeling Thinking" into the teaching reform of advanced mathematics courses is a dynamic and evolving process. Guided by this philosophy, teachers must flexibly adjust their teaching strategies and content to accommodate the characteristics of students' majors, their foundational mathematical abilities, and current events. This requires regular collection and incorporation of valuable feedback from students, peers, and industry experts to continuously refine and enhance teaching methods. Through the intertwining of practice and research, teachers can constantly distill and improve teaching models, ensuring that teaching activities evolve with the times and fully meet students' learning needs and the developmental demands of the era.

5. Conclusion

This paper integrates the STEM education philosophy with mathematical modeling thinking to construct an advanced, continuously evolving mathematics teaching system. Addressing the disconnect between theory and practice in traditional teaching, this model focuses on solving real-world problems in science and engineering through a series of practical teaching activities. This approach allows students to tangibly experience the application of mathematics, significantly stimulating their learning enthusiasm and initiative. By tackling actual challenges, students not only enhance their mathematical literacy but also strengthen their comprehensive qualities and problem-solving abilities, which can be effectively applied in other disciplines. In this process, the teacher's role shifts from a mere knowledge transmitter to a guide, supporter, and facilitator of the learning process, further cultivating students'

independent thinking, problem analysis, problem-solving, and innovation capabilities, thereby promoting better teaching outcomes.

Acknowledgments

This work is supported in part by the Teaching Research Project of Quality Engineering in Anhui Province under Grant 2022jyxm658 and Grant 2021jyxm0608; in part by the Teaching Research Project of Quality Engineering at Anhui Xinhua University under Grant 2023jy011.

References

Fang Zhaoyu. (2024). Competency-Based STEM Education: Concepts, Objectives, and Practice Models - A Comparative Study of the United States, France, and Singapore. *World Education Information*, *37*(1), 60-70.

Liu Xiaogang, Wang Zhen, Zhang Peijun, et al. (2022). Exploratory Research on Blended Teaching of Mathematics Courses in Colleges and Universities under the Concept of STEM Education. *Advanced Mathematics Research*, *25*(4), 124-127.

Liu Xu, & Li Xiuling. (2020). Research on Modular Teaching Reform Strategy of Advanced Mathematics Based on OBE Educational Concept. *Journal of Changchun Normal University*, 39(8), 159-161, 182.

The Central Committee of the Communist Party of China on the 14th Five-Year Plan for National Economic and Social Development and the Long-Range Objectives Through the Year 2035. [2022-05-13]. https://china.huanqiu.com/article/40YEJvUUD7.

Wang Youwen, Gao Zhenguo, & Liu Taofeng. (2022). Teaching Strategies of STEM Education in Advanced Mathematics Teaching. *Journal of Guangxi College of Education*, *2022*(6), 150-154.

Wei Jinjin. (2019). Research on Improving the Teaching Quality of "Advanced Mathematics" by Using Mathematical Modeling Ideas and Visualization Teaching. *Wireless Internet Technology*, *2019*(14), 78-79.

Wen Xuejun. (2024). Exploration of Integrating OBE Educational Concept and Mathematical Modeling Idea into Advanced Mathematics Teaching. *Shanxi Youth*, *1*, 114-116.