Research and Practice on the Innovation of Mathematics Modeling Course Teaching Based on the "5E Model + Dual Integration" Approach

Gaofeng Liu*, Tianqi Luo, Jun Wang
Leshan Normal University, Leshan, Sichuan, China
**Corresponding Author.*

Abstract: The course "Mathematical Modeling" is one of the core courses in the Mathematics and Applied Mathematics major at universities, with a strong focus on cultivating students' mathematical thinking and practical application abilities. However, traditional teaching methods face challenges such as a lack of systematic structure, weak practical components, and students' insufficient ability to handle complex problems. Based on the student-centered teaching philosophy, this paper proposes an innovative teaching model, the "5E Model + Dual Integration". By establishing a systematic 5E teaching process, combined with dual integration strategies of industry-education integration and competition-education integration, the model enhances students' logical thinking, practical application skills, and comprehensive ability to cope with high-pressure competitions. The research results show that this model has effectively addressed pain points in teaching, improved teaching outcomes, and enhanced students' core competencies, demonstrating significant potential for broader application and dissemination.

Keywords: Student-Centered Development; 5E Model; Industry-Education Integration; Competition-Education Integration; Mathematical Modeling

1. Introduction

With the growing demand for innovative talent in society, the education system is actively adjusting to cultivate individuals who can adapt to the development of productivity in the new era [1]. As an important tool for developing students' logical thinking, practical application abilities, and innovation skills, the mathematical modeling course has garnered widespread attention. However, several issues in traditional mathematical modeling teaching methods have gradually become apparent, including an overemphasis on theoretical instruction, weak practical components, and students' lack of ability to solve complex real-world problems [2-4]. These issues have resulted in the current mathematical modeling courses being unable to fully meet the societal demand for highly qualified, application-oriented talent [3].

In response to these challenges, many scholars in recent years have proposed various teaching reform initiatives. Li introduced a practical exploration of the development of high school mathematical modeling course resources aimed at advancing students' thinking, emphasizing the improvement of students' thinking abilities through resource optimization and innovative practices [3]. Zhang, from the perspective of core competencies, studied how to systematically design and implement high school mathematical modeling courses, with the goal of enhancing students' practical application abilities [4]. Lan and Zhu discussed the significance of introducing mathematical modeling courses into middle school education, arguing that this not only helps to enhance students' mathematical thinking but also prepares them to better tackle complex problems [5]. Yu proposed a plan for systematically building a mathematical modeling education system based on the ADDIE model, aiming to improve students' practical skills and comprehensive competencies through a structured teaching approach [6].

In addition, some studies have focused on the introduction of new models such as online-offline blended learning and industry-education integration. For instance, Chen et al.

explored the teaching reform of the mathematical modeling course based on the online-offline blended mode, suggesting that this approach can effectively enhance students' learning outcomes [7]. Xie, on the other hand, focused on the development and practice of school-based mathematical modeling courses in high schools, proposing an innovative course design that combines school-based resources with actual teaching needs [8].

Although these studies provide valuable insights into the teaching reform of mathematical modeling, there are still some issues in practice, such as a lack of systematic structure and limited practical opportunities [5-8]. To further address these challenges, this study proposes an innovative teaching model based on the "5E Model + Dual Integration" approach. The 5E Model consists of five teaching phases: Engage, Explore, Explain, Elaborate, and Evaluate, aiming to facilitate a systematic teaching process that helps students gain a deeper understanding and application of the learned knowledge [9]. Dual Integration refers to Industry-Education Integration and Competition-Education Integration, incorporating real-world business problems and competition training into the classroom to enhance students' practical application skills and competition readiness [10-12].

The purpose of this study is to design and implement this innovative model, verify its effectiveness in enhancing students' mathematical modeling skills, and provide theoretical foundations and practical references for future reforms in mathematical modeling courses.

2. Research Background and Problem Analysis

2.1 Current Teaching Situation and Challenges of Mathematical Modeling Courses

As a core course in the Mathematics and Applied Mathematics major, the Mathematical Modeling course plays a crucial role in developing students' logical thinking, innovative thinking, and problem-solving abilities. By integrating mathematical theory with real-world problems, students can not only master mathematical tools and methods but also apply them flexibly in practical scenarios. However, the existing teaching model still has many shortcomings in addressing complex real-world problems and fostering students' practical and innovative abilities, necessitating systematic teaching innovation and reform.

(1) Lack of a Systematic Learning Process

The current mathematical modeling courses generally lack a systematic teaching process. Traditional teaching models are mainly centered on theoretical instruction, with insufficient structured teaching components, resulting in fragmented learning for students. The learning process often misses systematic phases such as engagement, exploration, explanation, elaboration, and evaluation, making it difficult for students to internalize knowledge into their own logical framework through a step-by-step deepening process. In this model, students are often in a passive learning state, relying more on memorization and formula application, which hinders a deep understanding of the knowledge and limits active exploration. Consequently, students' logical reasoning abilities are relatively weak, making it difficult for them to integrate and apply learned theories to solve real-world problems.

(2) Insufficient Practical and Innovative Abilities

One of the core objectives of mathematical modeling is to enable students to use mathematical tools to solve real-world problems through practice. However, current teaching content generally emphasizes theoretical instruction, with relatively limited practical opportunities, leaving students lacking exposure to real-world projects or problem-solving experiences. The course content largely revolves around classic cases in mathematical modeling, which, while useful for understanding basic steps and methods, cannot fully simulate the complexity of real-world problems faced by enterprises. As a result, students have limited hands-on practice opportunities in the classroom, making it difficult to test the effectiveness of their knowledge through real-world scenarios. This disconnect from real-world applications restricts students' ability to translate theoretical knowledge into practical skills, resulting in relatively weak innovation, problem-solving, and practical abilities.

Moreover, with the growing trend of industry-education integration, many scholars have proposed introducing real enterprise projects into the classroom. This approach not only helps students enhance their practical application skills but also improves their analytical abilities in addressing complex real-world problems. By aligning with actual business challenges, students can better apply mathematical theories to specific practices, thereby fostering innovative thinking and increasing their competitiveness in real-world work environments.

(3) Weak Competition Readiness

In recent years, mathematical modeling competitions have become an important means of enhancing students' comprehensive abilities. Through competitions, students can apply their knowledge to complex real-world problems while also developing teamwork skills and stress management abilities in high-pressure settings. However, the current curriculum offers limited opportunities for competition training and simulation. Although some courses include case studies, these cases are often relatively simple and lack the complexity needed to simulate real-world problem scenarios, making it difficult for students to gain sufficient practical experience. In high-pressure competition environments, students often struggle with teamwork, stress management, and quick adaptability when faced with complex problems, which affects their performance in competitions.

To help students better adapt to the high-intensity environment of competitions, the mathematical modeling course needs to incorporate more competition training and simulation exercises. By designing challenging and high-pressure competition scenarios, students can accumulate experience in a simulated competition environment, enhancing their ability to tackle complex problems during actual competitions. Additionally, teamwork training is crucial. Throughout the problem-solving process, students can learn how to divide tasks and collaborate with teammates, thereby improving their overall competencies.

2.2 Need for Teaching Innovation

Given the existing issues in the mathematical modeling course, teaching innovation is imperative. Reforms and innovations in the following areas can effectively enhance students' learning experience, strengthen their logical thinking, practical application, and competition readiness:

(1) Establish a Systematic Teaching Process

A major issue with traditional teaching models is the lack of a systematic structure. To address this problem, the course can adopt a systematic teaching process based on the "5E Model". The 5E Model includes five stages: Engage, Explore, Explain, Elaborate, and Evaluate, aiming to guide students in gradually deepening their understanding of the knowledge through clear teaching steps. In the Engage stage, teachers can stimulate students' interest by presenting real-life cases or mathematical problems. In the Explore stage, students conduct independent exploration and analysis of the problems. The Explain stage focuses on helping students understand and digest the issues encountered during exploration. The Elaborate stage involves more complex problem scenarios to deepen their comprehension of the learned knowledge. Finally, in the Evaluate stage, students engage in self-reflection or group discussions to assess their learning outcomes and problem-solving abilities. Through such a systematic learning process, students can transition from passive reception to active exploration, enhancing their logical thinking and knowledge internalization skills.

(2) Introduce Real-world Enterprise Projects and Practical Cases

To enhance the practical aspect of the mathematical modeling course, actual enterprise projects and real-world cases can be integrated into the classroom. Through collaboration with companies, teachers can design practical projects that match students' skill levels, combining theoretical knowledge with real-world problems. For example, students can work on solving actual production issues faced by companies, allowing them to understand the application of mathematical modeling in industrial settings and validate the effectiveness of their knowledge through practice. This approach not only improves students' practical skills but also fosters their innovative thinking and ability to solve complex problems. Additionally, the inclusion of enterprise projects offers students more exposure to real work environments, helping them face real-world challenges more confidently in their future careers.

(3) Organize High-intensity Competition Training and Simulations

To improve students' ability to cope under pressure, the mathematical modeling course should incorporate more competition training and simulation exercises. By designing complex competition scenarios, students can develop teamwork, stress management, and on-the-spot decision-making skills while solving real-world problems. During the simulated competitions, students need to collaborate to divide tasks and solve problems, which not only enhances their teamwork skills but also improves their performance in actual competitions. High-intensity competition training helps students remain calm when faced with complex issues and enables them to quickly devise effective solutions within limited timeframes.

3. Teaching Innovation Design and Implementation

3.1 Innovative Approach of the 5E Model and Dual Integration Mode

The teaching innovation model proposed in this study consists of two components: the 5E Model and the Dual Integration Mode (Industry-Education Integration and Competition-Education Integration), as shown in Figure 1.

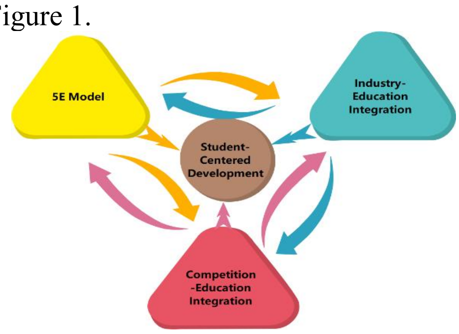

Figure 1. Innovative Approach of the 5E Model and Dual Integration Mode

To address the three major challenges in the teaching of mathematical modeling courses, the course team has proposed a "5E Model + Dual Integration" innovation approach centered on student development. The 5E Model refers to a systematic teaching process with five phases: Engage, Explore, Explain, Elaborate, and Evaluate, while Dual Integration refers to Industry-Education Integration and Competition-Education Integration.

By combining the 5E Model with Industry-Education Integration and Competition-Education Integration, an innovative student-centered teaching system is established. The 5E Model fosters active learning and deep thinking through its five phases, helping students better understand and apply knowledge in a diverse learning environment. Industry-Education Integration brings enterprise projects into the classroom, enabling students to connect theory with practice, thereby enhancing their practical skills and career competitiveness. Competition-Education Integration combines competitions with systematic training, honing students' ability to solve complex problems and strengthening teamwork and innovative thinking.

Together, these three components focus on student development: the 5E Model emphasizes self-directed learning, Industry-Education Integration focuses on practical skills, and Competition-Education Integration emphasizes real-world problem-solving and innovation. The 5E Model guides students from theory to practice, Industry-Education Integration provides real-world application scenarios for deeper understanding, and Competition-Education Integration tests learning outcomes through competitions, enhancing practical skills. These three elements form a tightly connected logical loop that drives continuous improvement in students' overall competencies.

3.2 Specific Implementation Plan

(1) Implementation of the 5E Model

The implementation plan of the 5E Model is shown in Table 1.

Table 1. 5E Flowchart Implementation Plan

Phase	Specific Measures
Phase 1: Engage	Teachers present real-life problems (e.g., double-glazed window efficiency) to spark students' interest and introduce learning content.
Phase 2: Explore	Students engage in small group discussions to explore issues, with the groups leading the discussion and teachers providing guidance.
Phase 3: Explain	Based on the discussion results, each group presents explanations, with the teacher offering supplementary explanations as needed.
Phase 4: Elaborate	Teachers promote deeper understanding through extended analysis, emphasizing the

	application of concepts in different contexts.
Phase 5: Evaluate	Through teacher feedback, self-assessment, and peer evaluation, students reflect on and summarize the entire modeling process, forming a feedback loop.

Engage Phase: Introduce real-world problems or cases related to the course content to spark students' interest and motivation, encouraging their active participation in classroom activities.
Explore Phase: Encourage students to engage in group discussions and independent exploration to conduct an initial analysis and solution of the introduced problem, forming preliminary modeling ideas.
Explain Phase: Through teacher guidance and student interaction, clarify concepts and methods to further deepen the understanding of the model.
Elaborate Phase: Require students to apply the acquired knowledge to more diverse problem scenarios, consolidating and expanding their modeling skills.
Evaluate Phase: Use group presentations, competition simulations, and reflective summaries to evaluate students' learning outcomes from multiple dimensions.
(2) Implementation of Industry-education Integration
In the systematic teaching process of the 5E Model described above, although it involves the introduction and application of real-world problems, it is essential to emphasize real-world problems as the core element of course engagement, stimulating students' interest and motivation through authentic cases.
In the collaborative teaching model with enterprise involvement, industry experts enter the classroom to directly share the complex problems encountered in real operations, providing a detailed explanation of the problem background. Through this approach, students can gain a deep understanding of industry needs and, through classroom learning and discussion, attempt to offer data-driven solutions to the enterprise's problems.
(3) Implementation of Competition-education Integration
By organizing mathematical modeling competition training camps, students receive systematic training and hands-on exercises related to competition knowledge. The training camp includes practical exercises, online and offline guidance, and expert seminars, led by experienced teachers and outstanding participants as mentors. The content covers fundamental modeling theory, algorithms, and case analysis. Through simulated competitions, teamwork, and problem-solving, students significantly enhance their modeling skills and algorithm application, develop the ability to tackle complex problems, and are well-prepared for national and international mathematical modeling competitions. Outstanding students also receive recognition.
Guided by the innovative "Competition-Education Integration" approach, students are encouraged to actively participate in the "Two Competitions" (China Undergraduate Mathematical Contest in Modeling (CUMCM) and the International Mathematical Contest in Modeling (MCM/ICM)), improving their ability to solve complex problems under high pressure and strengthening teamwork skills.

4. Analysis of Teaching Outcomes

4.1 Improvement in Students' Systematic Learning Abilities

The introduction of the 5E Model helps students progress through the five phases of engagement, exploration, explanation, elaboration, and evaluation during the learning process, significantly enhancing their logical thinking and knowledge internalization abilities. By the end of the course, students are able to more systematically apply theoretical knowledge to solve real-world problems and demonstrate stronger critical thinking skills in their post-course reflections.

4.2 Improvement in Students' Practical and Innovative Abilities

Through the implementation of Industry-Education Integration, students gained valuable practical experience in enterprise projects. Survey data shows that students participating in industry-education integration projects demonstrated higher levels of innovation and practical skills when addressing real industrial problems. Additionally, students gradually developed interdisciplinary thinking and the ability to analyze problems from multiple perspectives during the problem-solving process.

4.3 Improvement in Students' Competition Skills

The Competition-Education Integration teaching model has greatly enhanced students' ability to handle high-pressure competition environments. Compared to the period before the reform, the number of student awards in national and international mathematical modeling competitions has increased significantly. Data analysis shows that, since the introduction of this teaching model, the proportion of award-winning students has risen year by year, and for the first time, students won the M Award and H Award in the American Mathematical Contest in Modeling, breaking the long-standing bottleneck in international competition achievements.

5. Conclusion and Future Research Directions

The "5E Model + Dual Integration" teaching approach for the mathematical modeling course, with its systematic teaching process, practical teaching through industry-education integration, and competition training via competition-education integration, effectively addresses the challenges of traditional teaching models. The study demonstrates that this approach significantly enhances students' logical thinking, practical skills, and competition abilities, providing valuable insights for the reform of mathematical modeling course teaching.

Future research could further explore how this model can be applied to other subject courses, especially in integrating industry-education resources within interdisciplinary education to create a multi-dimensional, cross-disciplinary teaching innovation model.

Acknowledgments

This paper is supported by the following projects:

(1) Practical Research on the Path of Mathematics Culture Education in Teacher Education under the Educational Mathematics Ideology, a 2023 key project of the Higher Education Scientific Research Planning by the China Association of Higher Education (Project No. 23SX0301).

(2) Exploration of the Practice of Building First-Class Courses in Mathematics and Applied Mathematics through Digital Empowerment in Teacher Education Institutions, a 2023 research project on educational information technology by the Sichuan Provincial Educational Informatization and Big Data Center & Sichuan Provincial Educational Technology Center (Project No. SJZXKT238).

(3) Research on Ideological and Political Education Cases in the Numerical Analysis Course, conducted by the Provincial-Level Demonstration Center for Ideological and Political Education Research in University-Level Courses at Leshan Normal University (Project No. SJZX2415).

(4) Progressive Cultivation Project for Undergraduate Program Construction, specifically for the "Mathematics and Applied Mathematics Key Construction Program Team" (Project No. ZYDJ-2023-5).

(5) Ministry of Education's Industry-Education Collaboration Project, focusing on "Innovative Experimental Teaching of Mathematical Modeling Courses for Teacher Training Programs" (Project No. 230907027270358).

(6) University-Level Integrated Development Teaching Reform Project, focused on "Exploration of the 'Four Integration' Teaching Reform in the Numerical Analysis Course" (Project No. RHJG-2023-13).

References

[1] Dong Bangyuan. Cultivating Innovative Talents Adapted to the Development of New-Quality Productivity. People's Forum, 2024, (15): 68-70.

[2] Li Jianjun, Jiao Yan, Zhong Yonghui. Application of Mathematical Modeling in the Teaching of Architecture Courses. Earthquake Engineering and Reinforcement Renovation, 2024, 46(04): 187.

[3] Li Xianyong. Practical Exploration of Resource Development for High School Mathematical Modeling Courses Aimed at Advancing Thinking. Mathematics Bulletin, 2024, 63(07): 6-10+15.

[4] Zhang Wentao. Construction and Implementation of High School Mathematical Modeling Courses Guided by Core Competencies. Journal of Chinese Education, 2024, (02): 1-8.

[5] Lan Xiaoyin, Zhu Wenfang. Significance and Value of Integrating Mathematical Modeling into Middle School Courses. Journal of Mathematics Education, 2023, 32(03): 8-12.

[6] Yu Shiyang. Construction and Practice of

the Mathematical Modeling Education System Based on the ADDIE Model. Collection of Science and Education, 2024, (17): 62-65.

[7] Chen Mingsong, He Minyuan, Chen Xiaoguan. Teaching Reform of Mathematical Modeling Courses Based on Online-Offline Blended Mode. Science & Education Guide, 2024, (22): 145-147.

[8] Xie Zhanshou. Exploration of the Development and Practice of High School Mathematical Modeling School-Based Courses. Qinghai Education, 2024, (06): 31-32.

[9] Fan Xueshuang, Li Yunjuan. Practice of Integrating Ideological and Political Elements into Mathematical Modeling Courses. Modern Business & Industry, 2024, 45(14): 244-247.

[10] Li Yuqi, Sun Youping, Li Bing, et al. Exploration of Teaching Reform for Mathematical Modeling and Computational Methods Courses Based on "Engineering Orientation". Science & Technology Vision, 2024, 14(17): 12-15.

[11] Ma Heping, Li Beibei. Research on the Reform of Mathematical Model Courses Based on Mathematical Modeling Competitions. Modern Vocational Education, 2024, (15): 93-96.

[12] Ma Wenhui. Exploration of Teaching Reform by Integrating Mathematical Modeling into Higher Mathematics Courses. Knowledge Repository, 2024, 40(08): 147-150.

