Research on the Mechanism and Pathways of Feedback from Mathematical Modeling Competition Achievements to Postgraduate Mathematics Teaching

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Abstract: As a high-level academic competition, the National Postgraduate Mathematical Contest in Modeling (NPMC) features cutting-edge, interdisciplinary, and practical characteristics in its problem sets, which align closely with the inherent demands of current postgraduate mathematics education reform. However, the valuable outcomes of the contest have long been confined to a limited number of participating faculty and students, failing to benefit a broader postgraduate population. This study aims to break down this barrier by exploring the mechanisms and pathways through which competition outcomes can feed back into postgraduate mathematics teaching. The paper first analyzes the essence of this feedback, encompassing the transformation of knowledge content, thinking methods, and teaching models. It then systematically constructs a three-layer mechanism model (the Resources-Process-Culture model) from the dimensions of resource transformation, capability transfer, and cultural infiltration. Finally, a four-in-one feedback pathway is proposed: centered on case library development, driven by curriculum module restructuring, powered by innovative teaching models, and supported by evaluation system reform. This study provides a theoretical framework and practical guidance for transforming the elite outcomes of the competition into inclusive generalized teaching resources, offering significant reference value for deepening postgraduate mathematics education reform and enhancing the innovative and practical capabilities of postgraduates.

Keywords: Mathematical Modeling Competition; Achievement Feedback Integration; Instructional Pathway; Postgraduate Education

1. Introduction

The National Post-Graduate Mathematical Contest in Modeling (hereinafter the Contest), after nearly two decades of development, has become one of the largest and most influential series of innovative practice activities for postgraduates in China and an important benchmark for measuring their innovative and practical capabilities. The competition's problem sets are closely aligned with national strategic needs and cutting-edge industrial developments, often originating from real-world frontier challenges in fields such as aerospace, information technology, biomedicine, economics, and finance. Characterized by distinct interdisciplinary integration, open-ended problem-solving, and technological relevance, these problems aptly embody the profound insight that "mathematical technology is key to critical technologies." The Mathematical Modeling Competition provides a comprehensive platform integrating real-world problem exploration, academic exchange, and teamwork. It effectively stimulates graduate students' learning initiative and nurtures their innovative spirit and practical abilities, offering important support for further deepening the reform of graduate training mechanisms, implementing the Graduate Education Innovation Plan, and ultimately promoting the comprehensive improvement of training quality [1].

However, a prominent contradiction has emerged: on the one hand, the competition has accumulated an exceptionally rich and high-quality repository of “problem-model-algorithm-paper” outcomes, which can be regarded as a "gold mine" for teaching reform; on the other hand, the teaching of routine mathematics courses for graduate students (such as *Numerical Analysis*, *Applied Statistics*, and *Optimization Methods*) still suffers, to varying degrees, from issues such as outdated content, monotonous methodologies, and disconnection from professional applications [2,3]. A significant value gap exists between the elite-oriented and short-term nature of the competition and the mass-oriented and regular character of classroom teaching. As a result, despite mastering a wide array of mathematical tools, students often struggle to apply them effectively in their own research domains, leading to a disconnect between learning and application.

At present, some instructors have consciously incorporated competition problems into their teaching [4]. However, most efforts remain at the superficial stage of illustrative examples, lacking systematic refinement and transformation. As a result, the pedagogical value of competition achievements has been significantly underestimated. This disconnect between competition and teaching leads to a substantial waste of high-quality educational resources. Consequently, how to systematically and efficiently channel the outcomes of competitions back into routine graduate mathematics instruction, transforming them from a singular output of an elite competition into a diversified empowerment for inclusive education, has become an urgent task for deepening the reform of graduate mathematics teaching and enhancing the quality of innovative talent cultivation.

Integrating the achievements of mathematical modeling competitions into postgraduate mathematics education has become a widely focused research direction among scholars. Mu et al. [5] and Cao et al. [6] explored reform pathways for incorporating mathematical modeling concepts into postgraduate mathematics teaching from the perspectives of both content and methodology, aiming to strengthen students' mathematical modeling capabilities. Cao et al. [7] and Liu et al. [8], respectively, examined the reform of case-based teaching in postgraduate mathematics courses from the angles of mathematical modeling competitions and mathematical modeling thinking. They argue that such reforms can enhance students' interest in mathematics courses and stimulate their innovative thinking. Additionally, Zhou et al. [9] analyzed the role of mathematical modeling training and competitions in advancing the reform of fundamental mathematics courses for postgraduates, noting that the process also promotes the enhancement of instructors' teaching and research abilities. Liang et al. [10] also conducted research on the reform of postgraduate mathematics courses, advocating for the innovation of teaching methods and approaches through strengthening mathematical modeling instruction.

In this study, "feedback" refers to a purposeful, organized, and systematic educational transformation process. Its core involves deeply processing and designing high-quality content resources (competition problems), efficient procedural methods (modeling workflows), and advanced cultural concepts (innovation and collaboration) generated from competitions through pedagogical approaches, and then organically, and structurally incorporating them into the postgraduate mathematics curriculum system. This aims to universally enhance teaching quality and postgraduate innovation capabilities. This paper seeks to conduct an in-depth analysis of the underlying mechanisms of this integration and feedback process and outline clear, actionable implementation pathways.

2. The Connotation and Value of Feeding Competition Achievements Back into Teaching

2.1 An Analysis of the Connotation of Feedback

Feedback from Competition Achievements to Teaching is by no means a simple use of contest problems as illustrative examples, but rather, it represents an in-depth reshaping of the postgraduate mathematics teaching system and constitutes a multi-layered, profound transformation process.

2.1.1 The knowledge-content feedback from competition problems to didactic cases

The original competition problems are pedagogically adapted and broken down into classic cases, inquiry projects, or course designs suitable for different teaching stages, making them an excellent vehicle for connecting theory with practice.

2.1.2 The cognitive-methodology feedback from exercise-solving to problem-solving

The streamlined modeling processes derived from competitions are translated into teachable and trainable paradigms of scientific thinking, cultivating students' systemic and critical thinking skills.

2.1.3 The instructional-mode feedback from contest-based paradigms to routine teaching practices

By drawing on the competition's organizational format characterized by "team collaboration, self-directed inquiry, and time-bound completion", we can reform the traditional "teacher-centered lecturing and student-passive listening" classroom model and promote the regular adoption of modern pedagogical approaches such as problem-driven learning and team-based learning.

2.2 The Core Value of Feedback

2.2.1 Enriching the cutting-edge relevance and intellectual vitality of instructional content

Contest problems are rooted in technological frontiers and industrial practices, closely following the pulse of scientific advancement. Introducing them into classrooms can break the inertia of textbook content, rapidly update teaching materials, and transform the mathematical knowledge system from a closed and static state into an open and dynamic one. This allows students to engage with "living," evolving mathematical techniques, significantly stimulating their interest.

2.2.2 Resolving pedagogical challenges in interdisciplinary teaching

The inherently interdisciplinary nature of competition problems provides a ready-made, high-quality "adhesive" for breaking down barriers between mathematics and specialized courses. It also serves as an excellent "connector" and "testing ground" for the deep integration of mathematics with engineering, science, agriculture, medicine, economics, management, and other disciplines, thereby strongly promoting the cultivation of interdisciplinary talents.

2.2.3 Shifting from knowledge transmission to competency development

The feedback process itself is competency-oriented, compelling instruction to shift its focus from "whether one can calculate" to "whether one can apply". It guides students through the complete research workflow of "problem identification → hypothesis formulation → model construction → solution verification", systematically cultivating their problem-solving skills, innovative thinking, and research literacy, thereby directly enhancing the research innovation capabilities of graduate students.

2.2.4 Optimizing the allocation of teaching resources to achieve inclusive benefits from educational outcomes

Transforming competition outcomes into reusable, high-quality teaching resources significantly enhances the utilization efficiency and inclusive value of educational resources.

3. Constructing the Operational Mechanism for Feeding Competition Achievements Back into Teaching

Feedback is not a simple linear input, but rather a complex and dynamic systems engineering process. Its effective operation relies on a mechanism that functions from the surface to the core, layer by layer. This study constructs a three- tier "Resources- Process- Culture" mechanism model to reveal its underlying logic.

3.1 Surface Level: Resource Conversion Mechanism – Transforming "Competition Materials" into "Teaching Resources"

This is the foundational step of the feedback, whose core lies in its pedagogical adaptation.

3.1.1 Decomposition and reduction mechanism

Break down a complex, comprehensive competition problem into several sub-questions based on knowledge modules and cognitive rules. For example, a competition problem involving data mining can be decomposed into modules such as Data Preprocessing, Feature Engineering, Model Selection (e.g., SVM, Random Forests), and Model Evaluation, each corresponding to different chapters in courses like *Applied Statistics* or *Machine Learning*.

3.1.2 Standardization and normalization mechanism

Translate outstanding competition papers into standardized teaching cases following academic norms. Each case should include: problem background, teaching objectives, key knowledge points, detailed modeling process, comparison of multiple solution methods, annotated program code, error and sensitivity analysis, and extended reflections. This will form a structured and reusable case library.

3.1.3 Iteration and update mechanism

Establish a linkage mechanism between competitions and teaching resources, ensuring that new competition problems and outstanding papers are promptly incorporated into the teaching resource library each year. This guarantees the dynamic updating and cutting-edge relevance of the case database.

3.2 Middle Level: Skill Transfer Mechanism – Transforming "Competition Experience" into "Teaching Processes"

This is the core step of the feedback, centered on proceduralized training. It aims to transform the tacit knowledge acquired by competition elites under high-pressure conditions into explicit, replicable teaching processes, enabling ordinary students to achieve similar skill enhancement through classroom training.

3.2.1 Thinking externalization mechanism

In teaching, the focus shifts from merely presenting perfect models to emphasizing the reproduction of the process through which modeling ideas are generated. Through guided instruction, group discussions, mind mapping, and other methods, key thinking processes, such as how to extract information from unfamiliar problems, formulate hypotheses, and select mathematical tools, are externalized. This allows students to "see" thinking in action.

3.2.2 Collaborative learning mechanism

Introduce the team-based model from competitions into the classroom. In project-based learning, simulate the role division of competition teams by assigning positions such as team leader, modeler, programmer, and writer. This allows students to learn communication, task allocation, and integration through collaboration, fostering team spirit.

3.2.3 Practical simulation mechanism

During the teaching process, incorporate a Mini Mathematical Modeling session. Students are assigned a simplified competition-style problem and are required to complete the entire process—from modeling to abstract writing—within 8 to 24 hours. This simulates the practical intensity of real competitions, training their time management and rapid learning abilities under high-pressure conditions.

3.3 Deep Level: Cultural Integration Mechanism – Transforming "Competition Culture" into "Teaching Culture"

This represents the highest level and ultimate goal of the feedback, with cultural integration at its core. It aims to foster a classroom culture that values innovation, encourages exploration, and tolerates failure.

3.3.1 Problem-oriented cultural immersion

Taking the real-world, complex, and interdisciplinary problems represented by competitions as the starting point of teaching, this approach subtly cultivates students' awareness of paying attention to reality and raising questions. It replaces the "textbook-exercise-oriented culture", thereby fostering an academic character in students that emphasizes attentiveness to reality, courage to question, and willingness to challenge.

3.3.2 Open and inclusive cultural immersion

Competition problems typically have no standard answers. This concept is brought into the classroom by encouraging students to propose multiple models and solutions for the same problem and engage in debates. The evaluation criteria shift from correct answers to reasonable processes, strong innovation, and clear articulation, fostering an open and inclusive academic atmosphere.

3.3.3 Excellence-seeking cultural immersion

By showcasing outstanding competition papers from previous years, academic benchmarks are established. This allows students to recognize gaps through comparison, stimulating their intrinsic motivation to "refine continuously and strive for excellence". The competitive spirit is thus transformed into a rigorous attitude toward daily learning.

4 Design of Implementation Pathways for Feeding Competition Outcomes back into Teaching

Based on the aforementioned three-tiered mechanism of action, a set of interlinked implementation pathways must be designed to ensure the grounding and effective execution of the feedback process into practice.

4.1 Pathway 1: Focus on Building a "Case Database" to Solidify the Resource Foundation for Feedback Integration

To systematically transform the outcomes of mathematical modeling competitions, an interdisciplinary team composed of mathematics professors, subject-area instructors, and educational technology experts has been formed. This team conducts systematic review and pedagogical development of competition problems from the past decade as well as nationally award-winning papers. Based on disciplinary characteristics, the materials are categorized into three major types: STEM-Academic, Economics-Management-Social Sciences, and Bio-Medical Interdisciplinary, and further subdivided into subcategories such as optimization and control, data analysis, and machine learning. Each case undergoes multidimensional tagging, indicating its technical approach, difficulty level, and prerequisite knowledge. Through pedagogical adaptation, standardized resource packages containing five core components are created: comprehensive teaching plans, standardized datasets, executable code packages, selected reference literature, supporting micro-videos. Ultimately, a digital, searchable, and tiered teaching case database is established, enabling educators to flexibly select appropriate content for differentiated instruction based on course objectives and student proficiency levels.

4.2 Pathway 2: Prioritize the Restructuring of “Course Modules” to Achieve Systematic Integration of Feedback

To break down the knowledge barriers between traditional courses, we have designed a dual-track course integration mechanism that combines immersive and thematic approaches. This systematically develops course modules and teaching syllabi that are deeply integrated with various professional fields while highlighting the distinctive features of mathematical modeling.

4.2.1 Immersive approach

By integrating pedagogically adapted small competition cases as theoretical illustrations or chapter application exercises in core compulsory courses such as *Matrix Theory* and *Numerical Analysis*, students can not only learn classical theories but also intuitively experience their power in solving cutting-edge interdisciplinary problems. This achieves a positive interactive cycle of learning through application and applying through learning.

4.2.2 Thematic approach

Independent thematic courses or short-term projects, such as *Mathematical Modeling and Scientific Computing* and *Advanced Data Analysis Practice*, are offered. These courses are centered on 1–2 complete classic competition problems as the main thread, systematically structuring the teaching content around the entire process of problem analysis, model construction, solution, and evaluation. The goal is to intensively cultivate students' comprehensive research and practical innovation capabilities in addressing complex real-world problems.

4.3 Pathway 3: Drive Innovation in "Teaching Models" to Activate Classroom Practices for Feedback Implementation

To fundamentally transform the traditional passive teaching model of "teacher lectures, students listen," we will vigorously promote a hybrid teaching approach integrating problem-based learning and team-based learning, forming a routine and replicable student-centered classroom framework. Before class, based on teaching objectives and student profiles, instructors will precisely select challenging real-world problems from the case database as project tasks. Student groups will immediately assume their roles, engaging in self-directed literature review, background knowledge acquisition, and preliminary solution design. This shifts their role from passive knowledge recipients to active problem explorers. During class, instead of delivering exhaustive lectures, instructors focus on explaining the core mathematical principles and key tools related to the problem. The majority of class time is allocated to student collaboration within groups. Teams concentrate on model construction, algorithm implementation, and numerical simulations. Instructors act as guides and facilitators, moving among groups to provide personalized guidance, stimulate thinking, and address technical challenges in real time. After class, each group is required to produce a formally structured and logically rigorous research report and prepare a final presentation. During a dedicated defense session, presenting groups must clearly articulate their modeling approach, solution process, and conclusions, while responding to on-the-spot questions and critiques from other groups. This process not only hones students' academic communication skills but also significantly deepens their critical thinking and rigor through constructive dialogue. Ultimately, this approach creates a complete teaching cycle of "Problem-Driven –

Team Inquiry – Practical Feedback", comprehensively enhancing students' innovation and practical capabilities [11].

4.4 Pathway 4: Reform the "Evaluation System" as a Safeguard to Guide the Realization of Feedback Values

To scientifically evaluate students' mathematical modeling capabilities and innovative competencies, a diversified assessment system is established, integrating process-based and summative evaluations, while linking individual contributions to team performance [12]. This system significantly reduces the weight of traditional final written exams and increases the emphasis on performance assessment throughout the entire project cycle. Process-based evaluation focuses on students' practical performance in team projects, with scoring based on: The completeness and standardization of the project research report, Detailed documentation and reflection on the modeling process, The quality and reproducibility of program code, Logical expression and collaborative skills demonstrated during team presentations. To encourage innovation, a special "Innovation Points" bonus is introduced, granting additional recognition to students who propose original insights in model construction, algorithm improvement, or solution design.

5. Analysis of Practical Teaching Effectiveness

To evaluate the effectiveness of the teaching reform, this study takes the graduate course *Scientific Computing and MATLAB* for the Electronic Information Engineering major at Tianjin Agricultural University as a case sample. A comparative analysis was conducted between the 2022 cohort, representing innovative teaching, and the 2023 cohort, which received traditional instruction. Figures 1 and 2 respectively present the comparison of final exam scores and overall assessment scores for the two cohorts.

As shown in Figures 1 and 2, the average scores, minimum scores, and maximum scores for the innovative teaching cohort are higher than those for the traditional teaching cohort, both in the final exam and overall assessment. This indicates that the innovative teaching method has effectively enhanced the overall learning level and knowledge mastery of the student group, demonstrating a positive impact on most students in the class and achieving better teaching outcomes compared to traditional instruction.

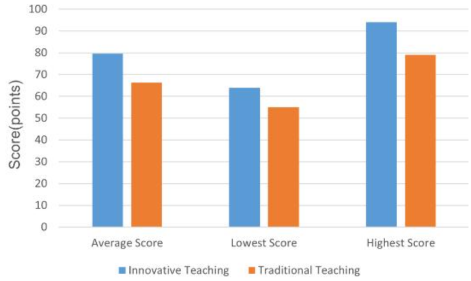

Figure 1. Comparison of Scores for Each Component of the Final Grades

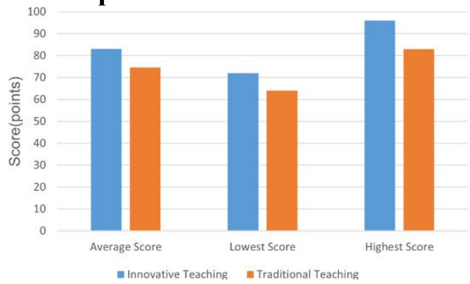

Figure 2. Comparison of Scores for Each Component of the Overall Assessment

6. Conclusion

The National Postgraduate Mathematical Modeling Competition is a rich repository brimming with potential for teaching reform. This study systematically proposes a three-tier feedback mechanism, "Resources-Process-Culture", and an integrated implementation pathway comprising "Case Database-Course Modules-Teaching Models-Evaluation System", providing both a theoretical framework and practical tools for systematically harnessing this repository. Feeding competition outcomes back into teaching is, in essence, a strategic shift in postgraduate mathematics education from a knowledge-based to a competency-based approach. It is not merely an update of content but a reshaping of thinking and a reconstruction of culture. Future research could further focus on the quantitative assessment of feedback effectiveness and the development of more intelligent case recommendation and learning analysis systems based on artificial intelligence technologies. We firmly believe that through sustained and in-depth exploration and practice, the spark ignited by competitions will surely spread across the vast landscape of postgraduate mathematics teaching, fueling a widespread enhancement in the quality of innovative talent cultivation.

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