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Practical Research on the Integration of Competition and Teaching in the Teaching Reform of Higher Mathematics Courses

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Abstract: *With the continuous improvement of the requirements of higher vocational colleges for the cultivation of applied talents, traditional higher mathematics teaching generally has problems such as knowledge fragmentation, disconnection from application, and low student interest in learning, which makes it difficult to meet the goal of cultivating compound technical and skilled talents. To this end, this paper introduces the "integration of competition and teaching" teaching model, deeply integrates the elements of mathematical modeling competition with higher mathematics courses, explores the integrated teaching path inside and outside the classroom, and solves the problems of insufficient practicality of courses and fragmented knowledge system. Based on the concept of integration of competition and teaching, this paper reconstructs the teaching content of advanced mathematics and builds a modular "theory + case + project" course system; by introducing typical competition cases, it strengthens the practical training of core modules such as functions, derivatives, extreme values, and maximum values. This paper uses hierarchical and graded task-driven, combined with knowledge mind mapping and modeling micro-projects, to promote knowledge internalization and application transfer; at the same time, it uses the smart teaching platform to realize the full-link learning closed loop of "personalized push-process evaluation-dynamic feedback", and improve students' ability to construct problems, build models and analyze results. The experimental data show that the students' academic performance in advanced mathematics, comprehensive modeling ability, learning interest and autonomous learning ability are significantly improved under the integration of competition and teaching model. The learning motivation score of the experimental group increased from 3.12 ± 0.41 to 3.85 ± 0.36, and the autonomous learning strategy score increased from 3.05 ± 0.43 to 3.79 ± 0.38. The F values were 25.128 and 22.346 respectively, and p was less than 0.001. The difference was extremely significant, which verified the effectiveness of this model in improving mathematics learning effects and application ability.*

Keywords: *Integration of Competition and Teaching; Advanced Mathematics; Mathematical Modeling; Modular Courses; Smart Teaching*

1. Introduction

With the continuous deepening of vocational education reform, higher vocational colleges have put forward higher requirements for the cultivation of students' comprehensive quality and practical ability. As an important part of the public basic courses of higher vocational colleges, higher mathematics not only undertakes the task of consolidating students' mathematical foundation and cultivating logical thinking ability, but also plays a supporting role in subsequent professional courses and practical work. However, the existing higher mathematics teaching generally has the problems of "focusing on theory but not application" and "focusing on indoctrination but not practice". This leads to students' low interest in learning, insufficient classroom participation, and weak knowledge application ability, which makes it difficult to meet the current needs of cultivating compound technical and skilled talents.

Based on this, this paper introduces the teaching model of integration of competition and teaching, reconstructs the higher mathematics teaching system around the progressive learning path of "course knowledge-case training-competition practice", innovates the classroom teaching model, and explores the effective integration path of mathematical modeling competition in higher vocational higher mathematics courses. Through empirical research, the effect of this model on improving students' mathematical knowledge mastery, modeling application ability, learning interest and autonomous

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learning ability is verified, aiming to provide a practical path for reference for the reform of public basic courses in higher vocational colleges and the cultivation of compound talents.

2. Related Works

In recent years, research on mathematics education reform has continued to deepen. Many scholars have systematically explored the development path and practical experience of mathematics education from the perspectives of different national backgrounds, teaching models and policy orientations, and formed rich theoretical results and practical inspirations.

Xie pointed out that in order to adapt to social development, primary and secondary school mathematics education has undergone many important reforms in the 60 years since the founding of New China, with both successful experiences and lessons. At present, it needs to reflect deeply on the reform experience in light of national conditions, learn from the development trend of international mathematics education, analyze the advantages and disadvantages of Chinese mathematics education, and promote the healthy development of education [1]. Ahl et al. pointed out that mathematics and language are both core subjects in the education system, but mathematics has stronger international applicability. Since the end of the 19th century, mathematics education research has gradually developed, and in the 1970s it became an independent discipline and established a special journal [2]. Pratt and Alderton explored how neoliberalism and neoconservatism work together through curriculum and teaching methods, focusing on the UK Teaching for Mastery in Mathematics (TfM). The study pointed out that although TfM has been shaped by policies as a solution to educational problems, it may limit students' mathematical subjectivity at the classroom level, bringing profound impacts on philosophy, politics and fairness [3]. Based on the background of Egyptian education reform, Makramalla and Stylianides explored the role of school-based teacher professional networks in promoting the de-memorization reform of mathematics teaching. Through case analysis of two schools, they found that teacher networks can strengthen or hinder the reform practices of individual teachers, revealing the important influence of teacher groups on the diffusion of curriculum reform under collective culture and their power dynamics [4]. Chen and Mu compared the mathematical achievements of China, the United States and New Zealand, and found that the teacher training in the United States and New Zealand tends to be open and professional, and the curriculum takes into account both theory and practice, and strengthens school-local cooperation [5]. Druken investigated the motivations of 33 American teachers to participate in 12 mathematics teaching and research courses, and found that teachers mainly use teaching and research courses to understand reform standards, pay attention to student thinking, improve teaching methods, promote collaboration, develop teaching materials and improve mathematical literacy, especially focusing on student thinking and policy understanding. The study believes that teaching and research courses can be used as a tool for educational reform practice recognized by teachers [6]. Rezat systematically reviewed the research on curriculum resources in mathematics education from 2018 to 2023, analyzing seven major research directions: role, content analysis, user research, effect, design, resource data and review. The results showed that textbook research still dominated, content analysis, user research and design research were the most common, and student resource use and digital resource data application were emerging hotspots [7]. Bohara introduced Project-Based Learning (PBL) through action research in four middle schools in Nepal to help teachers shift from traditional teaching to student-centered teaching. The results showed that PBL promoted student participation, mathematical contextualization and creativity cultivation, while helping teachers improve their teaching skills and professional development, which has reference significance for the promotion of PBL [8]. Huffaker et al. pointed out that the San Francisco School District implemented a mathematics reform to postpone the unified study of algebra in the ninth grade. The research tracking data showed that the mathematics course selection rate decreased in the early stage of the reform, and Asian students were greatly affected, but it was alleviated later through the acceleration option [9]. Verawati et al. reviewed the research on physics education in the past five years and found that abstract content, indoctrination-style teaching and lack of real-life connection led to a decline in student interest. They suggested improving participation through interactive inquiry teaching, contextualized curriculum and technology integration, while strengthening teacher training to solve the problems of test-oriented and unequal resources, and promoting physics education to be more attractive and practical [10]. Munter et al. interviewed the mathematics teaching leaders of 50 school districts in Missouri and found that leaders in non-metropolitan areas paid more attention to standardized test scores and adopted a corporate management model; while leaders in metropolitan areas paid more attention to educational equity and students' mathematics learning experience. Factors such as school district size and resources, and teaching philosophy affect problem identification and framing, and called for the formulation of education policies based on local conditions [11]. However, existing research has mostly focused on macro policies or single teaching strategies, lacking systematic exploration and empirical verification of the practical path of "integration of competition and teaching" for specific courses such as advanced mathematics.

3. Methods

3.1 Reconstruct Teaching Content, Integrate Competition Resources to Build a Modular Curriculum System

In view of the differences in knowledge base of higher vocational students from different backgrounds, especially the learning shortcomings in the modules of higher mathematics functions and derivatives, the course content has been modularly reconstructed. The survey shows that although general high school students are familiar with the operation of conventional functions and derivatives, they lack the understanding of their theoretical background; and the students of the three-two segment and secondary vocational students have weak basic mathematical skills due to learning gaps, and have almost no foundation in the derivative module. To this end, combined with the characteristics of the National College Students Mathematical Modeling Competition (higher vocational group) in the past three years, application cases that are highly related to the core knowledge points of higher mathematics are selected to build a modular curriculum resource that integrates "knowledge + cases". Classroom teaching focuses on basic standard training, sets up tiered and graded classroom exercises, strengthens basic mathematical skills, and enhances students' learning confidence. After-class homework adopts the trinity of "basic questions + extension questions + practical projects", taking into account both independent completion and group collaboration to improve students' comprehensive application ability.

At the same time, relying on the "Teddy Digital Modeling Intelligent Studio", the paper can build an online and offline integrated learning platform to realize the sharing of corporate case resources. By regularly conducting digital modeling micro-project practical training, the paper can provide students with continuous extracurricular practical support, expand the boundaries of the classroom, promote "combining learning with practice" and "unity of knowledge and action", and provide a stable growth channel for students who are interested in mathematical modeling.

3.2 Reconstruct Knowledge Logic and Create a Knowledge Chain of Integration of Competition and Teaching

With the development of artificial intelligence and smart education, higher mathematics teaching has shifted from traditional knowledge memory to ability integration. The current teaching model of integration of competition and teaching emphasizes the transformation from imparting a single knowledge point to building a knowledge system and cross-module integration. In the teaching of modules such as functions, limits, derivatives and their applications, a knowledge integration model driven by mathematical modeling competitions is introduced, focusing on breaking the chapter-based teaching method of textbook fragmentation and strengthening the systematic association of knowledge.

By guiding students to conduct modeling practices based on specific problems, the paper gradually establishes a knowledge network from point to line and from line to surface. For example, when teaching "derivatives and extreme values", it combines the modeling case of "optimization problems" to closely combine the logical deduction of mathematical concepts and the deduction process of formulas with actual application scenarios, helping students to complete knowledge reconstruction in the process of solving practical problems. The course no longer teaches modules such as definite integrals and differential equations in isolation, but connects various knowledge modules of higher mathematics through continuous modeling projects, promoting students to change from "learning knowledge" to "using knowledge" and "making good use of knowledge". With the help of the smart teaching platform, customized knowledge maps are generated according to students' learning progress and interests to achieve differentiated and customized learning paths.

3.3 Deepen Practical Transformation and Promote the Implementation of Classroom Results

The integration of competition and teaching model not only focuses on the mastery of knowledge in

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the classroom, but also emphasizes the actual transformation of knowledge achievements outside the classroom. In the teaching practice of higher mathematics, the competition projects are deeply integrated with real school-enterprise cases to guide students to carry out mathematical modeling analysis around practical problems. The teaching team is composed of "dual-teacher" teachers and front-line technical personnel of the enterprise, guiding students to complete verifiable and demonstrable model works according to the competition standards.

In the teaching process, this paper selects data analysis, optimization scheduling, benefit evaluation and other scenarios in the actual operation of the enterprise, and integrates them into module exercises such as "function modeling", "maximum value problem" and "extreme value determination" to promote students to truly use mathematical tools to analyze and solve practical problems. Students' excellent modeling works can be iteratively improved, combined with the company's new processes and new algorithms for optimization, and the industry-university transformation of knowledge achievements can be achieved by applying for software copyrights and patent applications. This practical path not only effectively enhances students' innovation awareness, but also broadens the depth of application of higher mathematics in practical scenarios.

3.4 Collaborative Incubation between Schools and Enterprises to Improve the Closed Loop of Application-Oriented Talent Training

In order to break the limitation of traditional higher mathematics teaching that "emphasizes theory and neglects practice" and build a complete education chain of "course- competition- application-transformation", colleges and universities actively introduced the school-enterprise joint incubation mechanism, established stable cooperative relations with many data analysis companies and intelligent algorithm companies, and signed teaching achievement incubation agreements. For students' winning projects and excellent modeling results in the modeling competition, the professional team of the enterprise can conduct project evaluation and provide full-process incubation support from solution optimization, data support to product prototype design.

At the same time, colleges and universities open mathematical modeling workshops and mathematical innovation laboratories, and enterprises simultaneously open algorithm libraries, case libraries, data interfaces and real project requirements to create a resource co-construction and sharing mechanism. In the process of periodic project incubation, students gradually complete the transition from classroom knowledge to practical application through the "topic-driven-phased display-centralized iteration" model. Finally, a mathematical modeling product solution that is both practical and innovative is formed, providing a replicable "integration of competition and teaching" model for serving local industries and promoting the connection between higher mathematics teaching and industry needs.

3.5 Strengthen the Construction of Teaching Resources and Optimize the Conditions for the Integration of Competition and Teaching

To ensure the effective implementation of the integration of competition and teaching model for advanced mathematics and further strengthen practical teaching conditions and resources, this paper improves mathematical modeling laboratories, regularly updates commonly used mathematical modeling software such as Matlab, Python, and R, and enriches online resources such as micro-lecture videos, case libraries, and competition question banks to ensure the smooth operation of students' "in-class learning + out-of-class practice + post-class competition" learning process.

Universities have also collaborated with mathematical modeling competition experts to develop training courses suitable for students at different foundation levels. These courses are divided into four stages: "foundation improvement - competition introduction - actual competition practice - application transformation," creating a step-by-step path to improving advanced mathematics proficiency. By introducing assessment methods oriented towards modeling ability and increasing the proportion of "process assessment + achievement demonstration," this can achieve a comprehensive shift from "teaching knowledge" to "teaching thinking" and "teaching skills," promoting the true integration of advanced mathematics courses into smart education and serving the development of professional capabilities.

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4. Results and Discussion

4.1 Experimental Subjects and Grouping

The experimental subjects were 120 first-year engineering students from a vocational college. Students were divided into the following groups using a cluster randomization method, balanced based on their basic mathematics scores and gender ratio:

Experimental Group (integration of competition and teaching Group): 60

Control Group (Traditional Teaching Group): 60

Both groups had similar basic advanced mathematics proficiency at the beginning of the semester. The teaching hours, instructor level, and textbook content were identical, with only the teaching methods differing.

The experimental group incorporated typical problems from the Mathematical Modeling Competition; set up "modularized case studies + practical projects"; guided students to engage in group modeling tasks; provided modeling micro-projects after class; and used visual knowledge maps to guide knowledge reconstruction.

The control group primarily used lectures and blackboard instruction, with uniform written homework assigned after class. No modeling tasks or competition-based practical tasks were assigned.

The intervention lasted 16 weeks (one semester) and covered advanced mathematics topics such as functions, limits, derivatives and differentials, the mean value theorem, and applications of derivatives.

4.2 Data Collection

(1) Pre- and post-assessment

Academic performance assessment uses a unified midterm and final test paper with consistent difficulty, including three types of questions: basic operations, understanding analysis, and application innovation.

Modeling ability assessment uses a small modeling task scoring scale, which includes four indicators: problem construction, mathematical model selection, result interpretation, and model evaluation, with a total score of 100 points.

(2) Process data

Weekly classroom observation records (teacher + third-party observation)

Students' completion of after-class tasks (comparison of completion rate of self-selected modeling projects and general exercises)

Teacher interviews, student group interviews (stage sampling)

Data processing was performed using SPSS 26.0. The specific analysis method is as follows:

4.3 Teaching Tools and Platforms

Teaching Support Platforms: Chaoxing Learning Pass + Lanmo Cloud Class.

Mathematical Modeling Software Tools: Matlab, Excel, GeoGebra (Visualization), Python (for some students).

Assignment and Feedback: WeChat group, online cloud form for answer collection, modeling project document submission and grading.

A comparative analysis of final semester academic performance of students under different teaching models is shown in Figure 1. The final score of students in the experimental group (integration of competition and teaching) was 81.4 ± 6.7, significantly higher than the control group (traditional teaching) score of 73.1 ± 7.5. The difference was highly significant ($t = 6.732$, $p = 0.000$). In terms of specific scoring dimensions, there was no significant difference in basic calculation scores between the experimental and control groups ($p=0.282$), indicating that the two groups maintained similar basic computational abilities. However, in theoretical understanding and application innovation, the experimental group achieved scores of 28.7 ± 2.9 and 28.4 ± 3.2, respectively, significantly higher than

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the control group's scores of 25.2±3.1 and 24.0±3.6, with p values less than 0.01, indicating highly significant differences, as shown in Figures 1a and 1b. This shows that the integration of competition and teaching model not only consolidates students' basic calculation ability, but also significantly improves students' understanding of advanced mathematical theories and their application and innovation capabilities in practical problems, verifying that this model has a good effect on promoting students' comprehensive mathematical literacy.

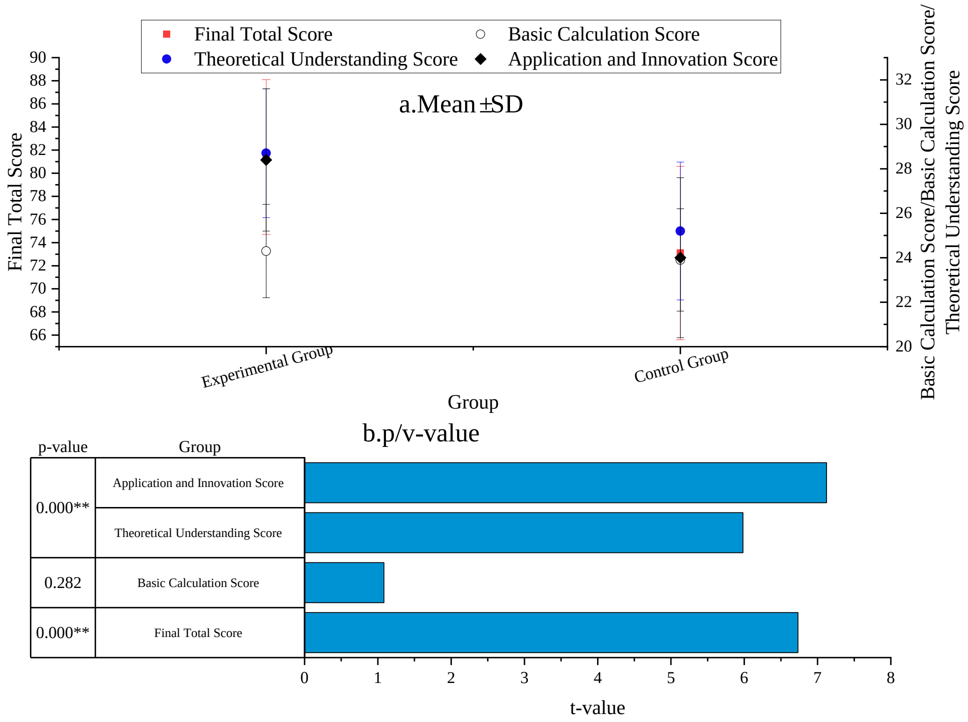

Figure 1 Comparison of Final Semester Academic Performance of Students under Different Teaching Models (Mean ±SD/n = 60)

*Note: **p < 0.01, indicating a highly significant difference.*

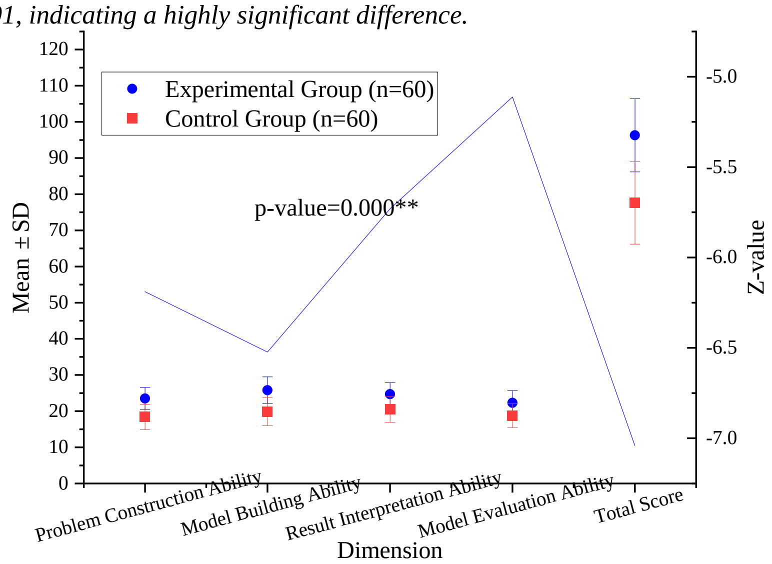

Figure 2 Comparison of Mathematical Modeling Ability Scores (maximum 100 points)

A comparative analysis of the mathematical modeling abilities of students in the experimental and control groups is shown in Figure 2. The experimental group's total mathematical modeling score was 96.3±10.1, significantly higher than the control group's 77.6±11.4, with a Z-score of -7.041 and p=0.000, indicating a highly significant difference. Looking at specific ability dimensions, the experimental group significantly outperformed the control group in the four areas of "problem-building ability," "model-building ability," "result interpretation ability," and "model evaluation ability," with

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Z-scores of -6.189, -6.523, -5.731, and -5.112, respectively, and p-values of 0.000, all reaching a highly significant level. The experimental group's scores were particularly strong in the core competencies of model building and problem construction. This demonstrates that through the integration of competition and teaching model, students not only benefited from theoretical learning but also effectively enhanced their core abilities in practical problem analysis and mathematical model construction, significantly strengthening their comprehensive modeling and applied analytical skills.

Table 1 Changes in Student Scores on the Learning Motivation and Autonomous Learning Ability Questionnaire

Indicator	Pre-test (Experimental Group) (Mean ± SD)	Post-test (Experimental Group) (Mean ± SD)	Pre-test (Control Group) (Mean ± SD)	Post-test (Control Group) (Mean ± SD)	F-value	p-value
Learning Motivation Score	3.12 ±0.41	3.85 ±0.36	3.15 ±0.39	3.32 ±0.42	25.128	0.000**
Autonomous Learning Strategy Score	3.05 ±0.43	3.79 ±0.38	3.10 ±0.44	3.29 ±0.40	22.346	0.000**
Learning Interest Score	3.18 ±0.39	3.90 ±0.33	3.21 ±0.40	3.35 ±0.41	28.673	0.000**
Classroom Participation Score	2.98 ±0.45	3.81 ±0.34	3.02 ±0.47	3.18 ±0.43	30.515	0.000**

The pre- and post-test changes in students' learning motivation and autonomous learning ability were analyzed, and the results are shown in Table 1. Under the integration of competition and teaching model, the experimental group's scores on learning motivation, autonomous learning strategies, learning interest, and classroom participation were significantly improved compared to the pre-test, and significantly outperformed the control group. The experimental group's learning motivation score increased from 3.12±0.41 to 3.85±0.36, and the autonomous learning strategy score increased from 3.05±0.43 to 3.79±0.38, with F values of 25.128 and 22.346, respectively, and p values of less than 0.001, indicating highly significant differences. In the dimensions of learning interest and classroom participation, the experimental group's post-test scores increased to 3.90±0.33 and 3.81±0.34, respectively, with F values of 28.673 and 30.515, respectively, and p values of 0.000. In contrast, the control group showed limited improvement in all dimensions, with significant gaps. The above results indicate that the integration of competition and teaching model not only improves students' cognitive experience of advanced mathematics, but also effectively stimulates their learning motivation and awareness of independent participation, significantly promoting the development of proactive learning behaviors.

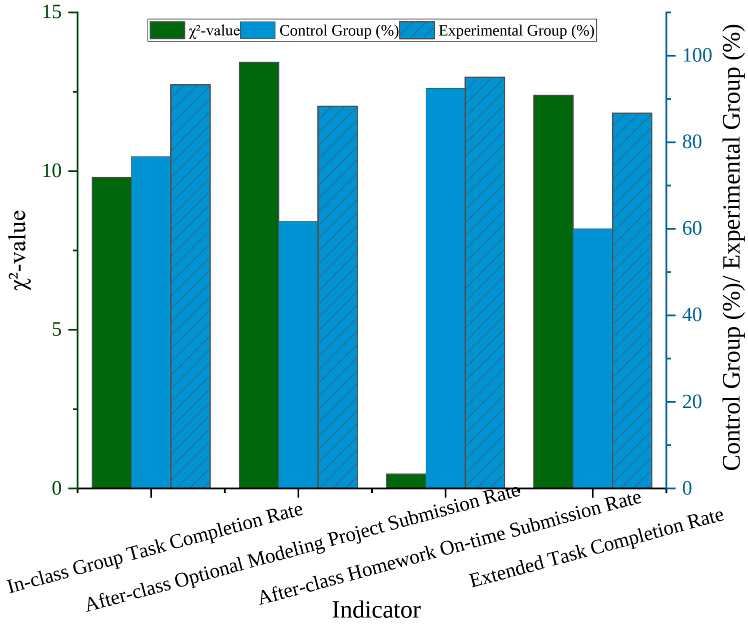

Figure 3 Comparison of Classroom Task Completion Rate and Homework Assignment Compliance Rate

Analysis of the comparison of classroom task completion rates and homework assignment completion rates reveals that the experimental group significantly outperformed the control group in completing multiple practical tasks. Specifically, the experimental group's classroom group task completion rate was 93.3%, significantly higher than the control group's 76.7%, with a χ^2=9.802,

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p=0.002, indicating a statistically significant difference. The experimental group's submission rate for the after-class self-selected modeling project was 88.3%, while the control group's was only 61.7%, with a $\chi^2=13.425$, $p=0.000$, indicating a highly significant difference. The experimental group achieved a completion rate of 86.7% for extended tasks, significantly higher than the control group's 60.0% ($\chi^2=12.387$, $p=0.000$). Notably, the difference between the two groups in the on-time submission rate for regular homework assignments was not significant ($p=0.500$), indicating that students completed regular homework at a high level. However, the integration of competition and teaching model significantly increased students' enthusiasm and execution in innovative and practical tasks, effectively promoting in-depth learning and the development of practical skills (Figure 3).

5. Conclusions

This paper, focusing on the current state of advanced mathematics teaching in higher vocational colleges, reconstructs an integrated teaching model based on the concept of "basic knowledge - case training - competition practice" based on the integration of competition and teaching. By introducing typical cases of mathematical modeling competitions, building modular course content, and integrating it with a smart teaching platform, a teaching approach is established that integrates in-class and out-of-class interaction and promotes tiered and classified learning. Comparative experiments have verified that this integration of competition and teaching model can effectively improve students' mathematical academic performance, theoretical understanding, and practical application skills, significantly enhance their learning interest and independent learning ability, expand their practical understanding of mathematical modeling, and promote the transformation of higher vocational mathematics courses from a "knowledge-transferring" to a "capacity-developing" approach. While this study demonstrated the positive effects of the integration of competition and teaching model in the short term, it still has some limitations. For example, the relatively short research period means that the long-term sustainability of teaching effects and their interdisciplinary transferability have not yet been fully verified. Future research can be expanded and validated over longer periods and within broader professional contexts, and combined with diverse intelligent teaching tools, to further deepen the reform path of integration of competition and teaching in foundational courses at higher vocational colleges.

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