Reform and Practice of Cooperative Teaching Method Research - Taking University Mathematics Courses as an Example

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Abstract: In response to the difficulties of “formalization”, “free-riding”, and “single evaluation” in cooperative teaching of university mathematics, this paper proposes a systematic teaching reform plan based on social interdependence and constructivist theory. Taking university mathematics courses as an example, the study reconstructs cooperative teaching from five dimensions: designing "ill-structured project" tasks, implementing heterogeneous complementary and dynamic rotating grouping, embedding social skills training, constructing a three-dimensional evaluation model of “group achievement + individual contribution + process performance”, and leveraging online platform technology. The results of a 16-week quasi-experimental study show that this systematic design effectively solves the problem of shallow cooperation, significantly improving students' cooperative skills, depth of participation, and higher-order problem-solving abilities. The findings suggest that effective cooperative teaching depends on structured systematic design, and university teachers should consciously transform into “learning designers” and “conflict mediators”.

Keywords: Cooperative Teaching; Teaching Reform; Ill-Structured Projects; Multiple Evaluation

1. Introduction

Cooperative teaching is an important way to cultivate critical thinking and innovative literacy, and it is of great value in changing the traditional “lecture-based” mode of university mathematics [1-3]. However, current practices are generally trapped in the dilemma of "resembling but not embodying the spirit": first, “formalized cooperation” that merely rearranges seats, lacking deep intellectual interaction; second, the “free-riding” phenomenon where top students monopolize tasks and weaker students are marginalized; third, “single evaluation” that over-relies on final exams, with insufficient quantitative assessment of the process, leading to a lack of student intrinsic motivation.The crux of these difficulties lies in the lack of systematic design. Based on social interdependence theory and constructivist learning perspectives, this study clarifies the logic of reform: abandoning the shallow model of “casual group discussion”, and transforming loose group learning into a structured, evaluable, and iterable collaborative inquiry system through task reconstruction, mechanism assurance, and technology empowerment.

2. Systematic Reform Design of Cooperative Teaching Methods

2.1 Task Design: From “Closed Problems” to “Ill-Structured Projects”

Traditional cooperative learning in mathematics often revolves around standard exercises from textbooks. Such "well-structured problems" have unique answers and lack room for discussion. The core of the reform design lies in introducing “ill-structured projects”, i.e., authentic, complex tasks that require collaboration to complete and have no standard answers. For example, in the course “Probability and Mathematical Statistics”, instead of simply having students calculate probabilities of a normal distribution, a project is designed: “Poisson Distribution Modeling and Dispatch Optimization of the Tidal Phenomenon of Campus Shared Bicycles”. Such project-based, case-based tasks require students to go through a complete cycle of data collection, model assumptions, formula derivation, and result testing, forcing students at different levels to utilize their strengths in different aspects such as modeling, calculation, and writing, making collaboration a necessity rather than a decoration.

2.2 Grouping and Roles: Heterogeneous Complementarity + Dynamic Rotation

To break the “free-riding” cycle, the principle of “heterogeneous complementarity” is adopted for grouping. Based on factors such as students' pre-test scores, cognitive styles (e.g., intuitive vs. logical), gender, etc., 4-5 students are divided into one group, ensuring inter-group homogeneity and intra-group heterogeneity.

More crucially, a mechanism of “fixed roles + dynamic rotation” is established. Four core roles are set within the group: team leader (responsible for overall planning and progress control), recorder (responsible for organizing derivation processes and meeting minutes), questioner (responsible for finding logical loopholes and proposing counterexamples, a particularly important role for mathematics learning), and spokesperson (responsible for final outcome presentation and defense). Roles are rotated after each cooperation cycle (approximately 3-4 weeks). This mechanism ensures that every student receives training in different dimensions of thinking, avoiding the solidification of abilities.

2.3 Interaction Mechanism: Embedding Social Skills Training

University students often possess a certain mathematical foundation but lack the social skills for constructive communication. Therefore, the reform embeds “pre-class micro-training” before formal cooperation. For example, using 5 minutes before class to practice phrases such as “how to listen without interrupting”, “how to use 'Yes, and...' to improve others' mathematical assumptions”, and “how to face questioning without becoming emotional”.

Meanwhile, “learning contracts” and “interaction record sheets” are introduced to regulate the process. At the beginning of the semester, group members jointly sign a contract clarifying attendance, preparation, and contribution baselines. During discussions, they are required to fill out an “interaction record sheet”, honestly recording who proposed key assumptions, who corrected calculation errors, etc., making social interaction visible.

2.4 Evaluation System: Three-Dimensional Model (Group Achievement + Individual Contribution + Process Performance)

The key to solving the problem of single evaluation is to establish a three-dimensional evaluation model with clear rights and responsibilities:

First, group achievement (50%): Based on the mathematical modeling report and case analysis solution jointly submitted by the group, all members share the basic score of this part, thereby strengthening the sense of “community of interests”.

Second, individual contribution (30%): Combining “intra-group peer evaluation” and “task segmentation”. The ill-structured project is broken down into subtasks; each individual is required to submit the part they are independently responsible for. At the same time, an intra-group peer rating scale is introduced, and the individual contribution score is adjusted by a coefficient based on the peer rating results, completely eliminating “free-riding”.

Third, process performance (20%): The teacher scores based on the detail of the cooperation logs and the fulfillment of roles (e.g., whether the questioner actually proposed valuable counterexamples).

2.5 Technology Assistance: Using Online Collaboration Platforms to Achieve Process Traceability and Feedback

Using online collaboration platforms such as “Rain Classroom”, “Tencent Docs”, or “Shimo Docs”, students are required to collaboratively edit the derivation process of mathematical formulas and data processing code in the cloud. These platforms not only support LaTeX input for mathematical formulas but also feature “version history” functions that can precisely capture each student's login time, number of edits, and annotation content. These digital traces provide an objective basis for the teacher's “process performance” evaluation and also facilitate the teacher's real-time intervention in cooperation bottlenecks, providing immediate feedback.

3. Reform Practice and Effect Analysis

3.1 Practice Design

This study conducted a 16-week quasi-experimental study in the “Advanced Mathematics” course for accounting majors at a certain university. Two parallel classes were selected: a control class (60 students) adopting the traditional model, and an experimental class (60 students) fully implementing the systematic cooperative teaching reform.

3.2 Implementation Process

The reform was not implemented overnight but went through an iterative process of “trial run — feedback adjustment — optimization and promotion”. Weeks 1-4 constituted the first trial run, which mainly revealed problems such as students' difficulty adapting to roles (especially the “questioner” who dared not question), and chaotic online collaborative editing of formulas. In response, in week 5, the teacher introduced “questioning sentence templates” and offered a 15-minute micro-course on the quick introduction to LaTeX formulas for online documents. Weeks 6-12 entered the second optimization phase, during which group operation gradually became smoother, and interaction shifted from "superficial agreement" to "in-depth debate". Weeks 13-16 were the outcome production phase, completing comprehensive modeling projects and conducting whole-class defenses.

3.3 Effect Data

Through multi-dimensional data collection, the reform effects were verified quantitatively and qualitatively.

(1) Quantitative Evidence

Using an adapted “College Student Cooperation Skills Scale” (5-point Likert scale) and platform backend data, the following comparative results were obtained. The results show that the experimental class exhibited a significantly steeper increase in the pre- and post-test curves for the two cooperation skills of “communication and coordination” and “conflict resolution”, while the control class showed an almost flat line; bar charts visually display that the experimental class had a clear advantage in the correct rate of higher-order problem-solving.

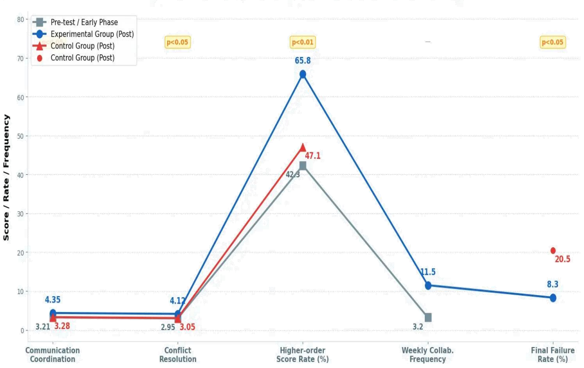

Figure 1: Comparative Analysis of Core Data between the Experimental Class and the Control Class

(2) Qualitative Evidence

Qualitatively, students' reflective journals provided rich evidence. One student wrote: “Previously, doing math problems meant each person calculating separately. Now, as a 'questioner', I have to find flaws in others' assumptions, which has deepened my understanding of the Law of Large Numbers tenfold.” Another student said: “With the peer evaluation mechanism, no one slacks off, because your negligence is directly reflected in the coefficient.” Group self-assessment reports also frequently contained expressions such as “we learned to find the optimal solution in disputes” and “the team leader's coordination doubled our efficiency”.

3.4 Existing Problems and Adjustment Strategies

Real challenges were also encountered in practice: First, some groups escalated mathematical disagreements into interpersonal conflicts. In response, the teacher intervened immediately, guiding students to distinguish between “regarding the matter (academic controversy)” and “regarding the person (emotional opposition)”, and using constructive conflict as an opportunity to deepen mathematical understanding. Second, the time cost increased significantly in the initial stage, squeezing the time for theoretical teaching. The adjustment strategy was to adopt the “flipped classroom” concept, moving basic concept explanations to pre-class online learning, and reserving valuable classroom time entirely for collaborative inquiry and the teacher's guided supervision.

4. Conclusion

This study shows that the key to truly effective cooperative teaching lies in the systematic design of “structured tasks + role interdependence + multiple evaluation”. This mechanism significantly enhances students' depth of participation, collaborative literacy, and higher-order problem-solving abilities. Based on the effectiveness of this practice, it is recommended that university teachers steadily start with single micro-tasks and consciously complete the role transformation into “learning designers” and “conflict mediators”. Of course, limited by the current single course sample, future research could further expand the scope, exploring more diverse collaboration models such as AI-assisted intelligence, blended online and offline learning, and interdisciplinary approaches.

Acknowledgements

This research was supported by the 2025 General Undergraduate Higher Education Teaching Reform Research Project of Liaoning Province (Project No.: 2025YBXM0742), for which we are grateful.

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