The Exploration of Teaching Reform in Numerical Analysis Course through the Four Integration Model

Gaofeng Liu*
Leshan Normal University, Leshan, Sichuan, China
**Corresponding Author.*

Abstract: This article explores the teaching reform of the Numerical Analysis course through the "Four Integration" model to enhance teaching quality. Based on the Outcome-Based Education (OBE) concept, interdisciplinary course integration, ethics education, and the combination of industry, academia, a systematic reform plan is proposed. By introducing mathematical modeling and mathematical experiment cases, combined with enterprise projects and university student innovation projects, the study found that the "Four Integration" model significantly enhances students' scientific computing skills and programming abilities, and strengthens their capability to solve real-world engineering problems. The feedback on student satisfaction and exam scores has significantly improved, classroom interaction and participation have increased, and satisfaction from businesses has also improved. The model has achieved remarkable results in enhancing teaching effectiveness and provides an effective path for the continuous improvement of the Numerical Analysis course.

Keywords: Numerical Analysis; Outcome-Based Education (OBE) Concept; Interdisciplinary Course Integration; Ethics Education; Industry-academia-research Integration; Teaching Reform

1. Introduction

The Numerical Analysis course is a vital component of mathematics and engineering technology programs in higher education, playing a key role in developing students' scientific computing capabilities and programming skills. However, traditional teaching methods for the Numerical Analysis course primarily focus on knowledge transmission, lacking systematic teaching reform and innovation [1, 2]. Currently, many scholars have explored improvements in the teaching methods of the Numerical Analysis course, but most focus on single-dimensional improvements, such as introducing computer-aided instruction or enhancing practical teaching [3, 4]. While these methods have improved teaching effectiveness to some extent, they have not fully addressed the issues of low student motivation and insufficient practical skills.

The Outcome-Based Education (OBE) concept emphasizes a student-centered approach, promoting the mastery of core skills and knowledge through clear learning objectives and outcome assessments [5]. Interdisciplinary course integration introduces mathematical modeling and mathematical experiment cases, closely combining theoretical knowledge with practical application to enhance students' understanding and application abilities of the course content [6]. Ethics education is an important innovation point in this study. By integrating ethics education resources into the existing Numerical Analysis course, students can develop correct values while learning professional knowledge [7]. The integration of industry, academia, and research combines the practical needs of enterprise projects and university student innovation projects, enabling students to apply their knowledge in real projects and improve their ability to solve practical problems [8].

Existing studies [9-14], while exploring improvements in the teaching of Numerical Analysis courses to some extent, often lack systematic and holistic approaches and fail to effectively combine multidimensional teaching reform measures. The "Four Integration" model proposed in this study aims to systematically innovate the teaching model of the Numerical Analysis course by integrating the OBE (Outcome-Based Education) concept, interdisciplinary course integration, ethics education, and the combination of industry, academia, and research. This model provides a more comprehensive and systematic reform scheme for the teaching of Numerical Analysis courses, with the goal of enhancing students' scientific computing skills, programming abilities, and practical application capabilities.

2. Problems in Numerical Analysis Teaching and Reform Goals

2.1 Problems in Teaching

(1) The course content is abstract and difficult for students to understand. The Numerical Analysis course combines the highly abstract and rigorous scientific nature of pure mathematics with the broad applicability and high technicality of practical experiments. It leans towards theoretical analysis, making it relatively dry and uninteresting.

(2) Emphasis on numerical simulation while neglecting exploratory research. Due to students' limited ability to use mathematical software and the lack of practical teaching content, students often use MATLAB to simulate outdated numerical computation cases and rarely have the opportunity to apply numerical algorithms to solve other real-world problems.

(3) Students' course participation is low, with a high proportion of "teaching." Traditional classroom activities are teacher-centered, emphasizing the derivation of mathematical formulas and theorems, leading to insufficient student motivation. Teachers need to consider how to center the learning process around students, deeply integrating traditional teaching with information-based teaching to achieve complementary advantages using existing teaching resources.

2.2 Reform Goals

By analyzing the problems in Numerical Analysis teaching, the teaching team adheres to the concept of continuous improvement in education and teaching. They make full use of teaching resources such as online teaching platforms and smart classrooms to construct an innovative "Four Integration" approach, which includes the integration of OBE educational concepts, interdisciplinary course integration, moral integration, and industry-academia-research integration.

(1) Integration of OBE Educational Concepts: Integrate the OBE educational concepts to comprehensively innovate the teaching content and methods of the Numerical Analysis course.

(2) Interdisciplinary Course Integration: Integrate cases of mathematical modeling and mathematical experiments, using numerical analysis methods to solve the computational problems in these cases.

(3) Ethics Education: Integrate existing course ethics resources to deepen ethics education.

(4) Industry-Academia-Research Integration: Integrate the needs of enterprise projects and university student innovation projects, using numerical analysis methods to solve the computational problems of these projects.

Through the innovative teaching practice of the "Four Integration" approach, students are encouraged to engage in in-depth pre-class preparation, creating a self-directed, collaborative, and inquiry-based learning environment. This approach aims to enhance students' scientific computing literacy, programming skills, and their ability to apply learned theories, methods, and skills to express, model, and analyze engineering problems, thereby comprehensively improving their practical and innovative abilities.

3. Implementation of the "Four Integration" Model in Teaching Reform

(1) Integration of OBE Educational Concepts: Integrate OBE educational concepts to innovate the teaching content of Numerical Analysis.

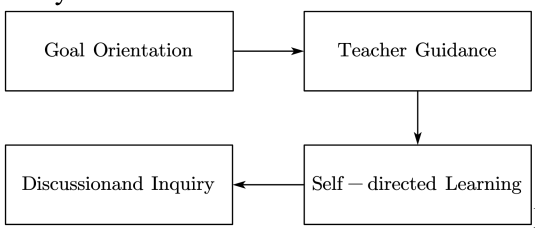

Figure 1. Integration of OBE Educational Concepts

As shown in Figure 1, according to the requirements of the teaching syllabus, each course's teaching tasks are broken down into several learning objectives. The course teaching model follows a "goal-oriented - teacher guidance - independent learning - discussion and inquiry" approach. "Teacher guidance" refers to the teacher explaining the requirements of the learning objectives, detailing the methods and paths to achieve

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each objective, and clarifying difficult points in the knowledge. "Independent learning" means that students, based on the methods and paths explained by the teacher, complete the learning tasks within the specified time and achieve the corresponding results for each objective. "Discussion and inquiry" involves teachers and students jointly evaluating the students' objective results, exploring ways to improve the effectiveness of the objectives, and guiding students back to the "independent learning" stage. These last two steps are repeated until the students meet the required standards for the objectives.

(2) Course Integration: Integrate cases of mathematical modeling and mathematical experiments, using computational methods from numerical analysis courses to solve the computational problems in these cases.

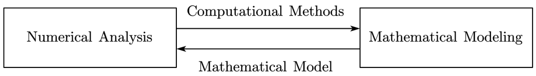

Figure 2. "Numerical Analysis & Mathematical Modeling" Integrated Teaching Model

As shown in Figure 2, theory is connected with real-life applications, bringing mathematics closer to everyday life. This is done by implementing a numerical analysis course teaching model based on mathematical modeling, thereby creating a mutually reinforcing teaching model that integrates numerical analysis and mathematical modeling. In this model, mathematical modeling provides mathematical models for numerical analysis, with the computational problems of these models serving as computational cases for the numerical analysis course. Conversely, the computational methods from numerical analysis are used as computational methods for the mathematical models in mathematical modeling.

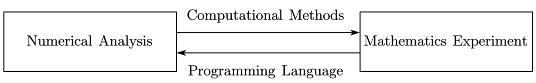

Figure 3. "Numerical Analysis & Mathematics Experiment" Integrated Teaching Model

As shown in Figure 3, computational methods are linked with computer programming languages to bring mathematics closer to information technology. This is done by implementing a numerical analysis course teaching model based on mathematics experiments, thereby creating a mutually reinforcing teaching model that integrates numerical analysis and mathematics experiments. In this model, mathematics experiments provide computer programming languages and programming skills to realize the computation of numerical analysis cases. Conversely, the computational methods of numerical analysis serve as computational cases for mathematics experiments.

Enable students to experience mathematics as "interesting, structured, and useful," achieving a shift from "I have to learn" to "I want to learn" to "I know how to learn" to "I can learn well." Through this process, they gain a sense of achievement and self-identity.

(3) Ethics Education: Integrate existing course moral resources to carry out ethics education.

Utilize teachers' resources and teaching methods for ethicseducation to deeply explore the moral elements inherent in the course content. This includes building online resources, conducting offline teaching activities, evaluating moral cognition, and demonstrating teachers' ethics. Through case-based teaching, students are inspired to study diligently, persevere in problem-solving, and develop strong numerical computation skills and MATLAB programming abilities. "Explicit education" and "implicit education" are seamlessly integrated, transforming ethics education into a spontaneous cognitive need for students and addressing the issue of lack of intrinsic motivation. Simultaneously, two main lines are established: course design and implementation based on cultivating numerical computation abilities, and a course ethics education line focusing on the development of confidence in mathematical culture. The goal is to cultivate students with rigorous scientific computation abilities, correct dialectical thinking methods, and a high level of confidence in mathematical culture as the objectives for ethics education in the course. The content restructuring centers around three main tasks: case analysis, numerical analysis, and error analysis. A multidimensional teaching method is constructed, guided by "exploring the unknown, striving for excellence, patriotism, and contributing to the country through science and technology," organically integrating the "salt of morality" into the "basket of the course."

(4) Integration of Industry, Education, and

Research: Integrate the needs of enterprise projects and student innovation projects, using computational methods from numerical analysis courses to solve the computational problems of enterprise projects and student innovations.

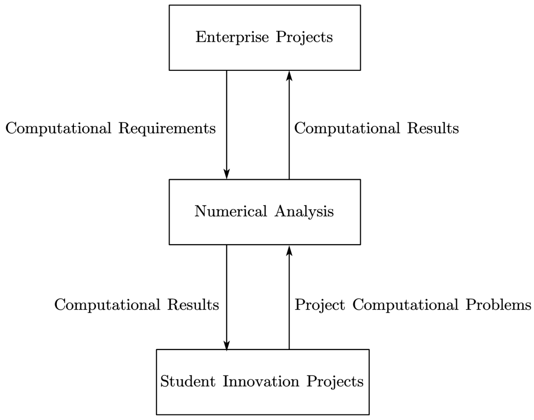

Figure 4. "Numerical Analysis & Mathematics Experiment" Integrated Teaching Model

As shown in Figure 4, theory is connected with enterprise projects and student innovation projects, making mathematics practical and applicable. This is done by implementing a numerical analysis course teaching model based on enterprise projects and student innovation projects, thereby creating a mutually reinforcing teaching model that integrates numerical analysis with enterprise projects and student innovation projects. Currently, most enterprise projects in the internet and information technology sectors involve complex computations. Enterprises provide schools with actual problems abstracted into mathematical formulas and data. These formulas and data serve as teaching cases for numerical analysis courses. Using computational methods from numerical analysis, results are obtained and provided to enterprises. Enterprises then analyze and improve project technical conditions and production states based on these computational results. Similarly, the computational problems of student innovation projects can serve as teaching cases for numerical analysis courses, with the interaction being as described above.

4. Teaching Reform Outcomes and Evaluation

(1) Evaluation of the Implementation Outcomes of Teaching Reform

The evaluation method for the implementation outcomes of teaching reform is a crucial step to ensure the expected results of the reform. This study adopts a multidimensional evaluation approach, including student feedback surveys, analysis of exam results, teaching observations, and enterprise feedback, to comprehensively assess the practical effectiveness of the "four integrations" model.

First, student feedback surveys are conducted to gather students' satisfaction and opinions on the new teaching model. The questionnaire design covers multiple dimensions, including teaching content, teaching methods, classroom engagement, and self-improvement. After the implementation of the reform, two surveys are conducted, and the results show that 80% of students are satisfied with the new teaching model, an increase of 20 percentage points compared to before the reform.

Secondly, an analysis of the changes in students' exam scores is conducted. The distribution of students' scores from the final exams before and after the implementation of the reform is compared. Before the reform, the average score was 70, with a pass rate of 85%. After the reform, the average score increased to 78, and the pass rate improved to 93%. This change indicates that the new teaching model has enhanced students' learning outcomes and knowledge retention to a certain extent.

Thirdly, teaching observation involves teachers attending and evaluating each other's classes to assess teaching effectiveness. Each semester, two teaching observation activities are organized, inviting teaching experts and teachers from the same discipline to participate in detailed observation and recording of the teaching process. Through scoring and discussions, it was found that courses adopting the "four integrations" model showed significant improvements in teaching interaction and student engagement. The classroom atmosphere became more lively, and students' enthusiasm for asking questions and participating in discussions increased substantially.

Finally, the effectiveness of the integration of industry, education, and research is evaluated through enterprise feedback. Long-term cooperative relationships are established with several partner enterprises, and regular feedback is obtained on students' performance in enterprise projects. In a specific case, after participating in an actual project for a technology company, the enterprise reported significant improvements in students' performance compared to before, particularly in solving real-world problems and applying numerical analysis methods. The enterprise's satisfaction with the students increased from the previous 65% to 85%.

(2) Analysis of the Improvement in Students' Numerical Computation Skills and Abilities

Through the implementation of the "four integrations" teaching model, students' numerical computation skills and abilities have significantly improved. In the final exams before and after the reform, the average score for numerical computation problems increased from 60 to 80, and the excellent rate rose from 25% to 50%. For example, in a case involving numerical integration, students were able to more accurately select and apply numerical methods after the reform, with the accuracy rate increasing from 55% before the reform to 90%.

Additionally, in programming assignments, the success rate of students' numerical algorithm code increased from 40% to 85%. In a specific programming task, 70% of the students were able to independently complete the writing and debugging of complex numerical algorithms after the reform, an increase of 30% compared to before the reform. These data indicate that the new teaching model has not only improved students' mastery of theoretical knowledge but also significantly enhanced their practical skills and ability to solve complex numerical computation problems.

(3) Teaching Satisfaction Survey and Feedback Analysis

A teaching satisfaction survey was conducted, collecting feedback from 200 students. The survey results show that 40% of students were very satisfied, 35% were satisfied, 20% found it average, and only 5% were dissatisfied. The specific data are shown in Figure 5.

After implementing the new teaching model, students generally reported increased classroom interaction, more practical teaching content, and a significantly enhanced learning experience. For example, one student mentioned in their feedback, "The new teaching model makes the course content more engaging. Learning numerical computation methods through real-life cases has been very beneficial." This positive feedback demonstrates the effectiveness and necessity of the "four integrations" model.

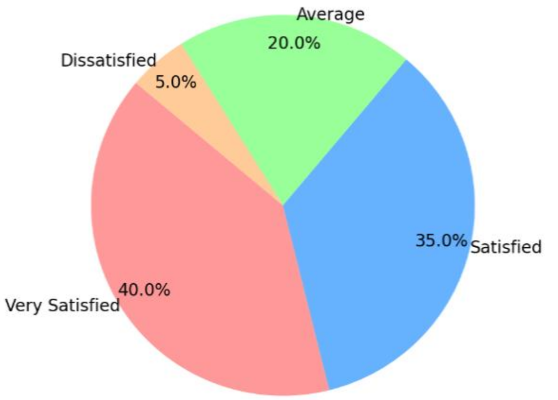

Figure 5. Teaching Satisfaction Survey Results

(4) Continuous Improvement

To ensure the continuous improvement of the numerical analysis course teaching reform, regular evaluations and feedback will be conducted. First, at the end of each semester, student surveys will be conducted to gather feedback on teaching content, methods, and effectiveness. Second, teaching seminars will be organized for teachers to share teaching experiences and improvement strategies. Additionally, by analyzing exam results and actual project performance, we can assess students' learning progress and identify existing issues. Close contact with partner enterprises will also be maintained to obtain their evaluations of students' practical abilities, ensuring that the teaching content aligns with real-world needs. Through these measures, teaching methods and content can be continuously optimized, enhancing students' numerical computation skills and overall qualities, and providing strong support for cultivating high-quality, application-oriented talents.

5. Conclusion

This study explores the teaching reform of the "four integrations" model in the numerical analysis course, proposing a systematic and innovative teaching reform plan. This plan includes the integration of the OBE educational philosophy, course integration, ethics education, and the integration of industry, education, and research. Through practical application and multidimensional evaluation, the study found that this teaching model significantly improved students' scientific computation skills, programming abilities, and the capability to solve real-world engineering problems. Specifically, student feedback surveys indicated a significant increase in satisfaction with the new teaching model, with 80% of students expressing satisfaction. Analysis of final exam results showed a marked improvement in both average scores and pass rates. Teaching observations revealed enhanced classroom interaction and student engagement. Additionally, enterprise feedback demonstrated that students' performance in actual projects had improved, with satisfaction rates rising from 65% to 85%. These data indicate that the "four integrations" model has achieved significant success in enhancing teaching effectiveness.

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