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Research on Blended Teaching of "Computational Methods" in the New Engineering Context Based on the OBE Concept

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Abstract: *By introducing the OBE concept into the teaching of computational methods, a blended teaching system based on the OBE concept has been established, which divides the teaching process into three stages: pre-class preparation, in-class instruction, and post-class consolidation. Teaching content construction is carried out in four aspects: teaching design, teaching methods, resource development, and teaching feedback, adapting to the teaching content and teaching methods in the context of the new engineering disciplines. The aim is to stimulate students' enthusiasm for learning and improve the teaching quality of computational methods.*

Keywords: *OBE, Blended Teaching, Computational Methods, New Engineering Context*

1. Introduction

Accompanied by the rapid development of computer technology and the increasing maturity of computational mathematical methods and theories, scientific computation, theoretical analysis, and experiments have become the three major means of scientific practice. Computational methods are the subject of scientific computation to explore and solve mathematical problems, and they are also effective tools for solving practical problems in other disciplines.

As a foundational course for undergraduate mathematics, big data science, information and computational science majors, it is also an elective course for many undergraduate and graduate students in science and engineering. The course content involves many disciplines, including advanced mathematics, linear algebra, and differential equations, and it forms its own theoretical system. It not only has the abstraction and rigor in theoretical mathematics courses, but also the practicality and experimental features in solving actual problems, and both its theoretical and practical aspects are strong. In today's rapid development of big data, cloud computing, and artificial intelligence, numerical analysis and methods in new engineering computational methods are becoming increasingly important [1-3].

In order to meet the challenges of new engineering education for higher engineering education, the return on educational investment and the actual output needs are receiving more attention. Starting from the 1980s, the learner-centered and learning outcome-oriented education model, Outcome-based Education (OBE), has become popular in Western education. Unlike traditional content-driven education models, the OBE model must clearly set the abilities and levels that students should achieve at graduation, then design the curriculum system in reverse, and construct the course content and course objectives to ensure that students can achieve the expected goals. Some universities in China have introduced the OBE educational concept into engineering major courses, combined with the trend of international engineering education reform, and have conducted exploration and practice [4]. This concept is becoming the guiding theory of talent cultivation in our country's universities and provides a reference for the construction of new engineering.

As the professional accreditation of domestic universities is carried out year by year, advanced educational concepts and methods, such as flipped classrooms and blended teaching models, are continuously introduced in the formulation of talent training programs and curriculum teaching reforms. Problem-oriented and outcome-oriented concepts are also gradually being explored and implemented in the talent training process. Currently, as an important part of the new engineering curriculum, the implementation of practical teaching in computational methods has become a consensus in the field of education. Although our college has done a lot of work in teaching philosophy and practical application,

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there are still many problems [5,6]. The specific problems are as follows:

(1) Mismatch of teaching and learning. Currently, this course is mainly taught by teachers from our college and is directed at a large number of engineering students. The course contains many lengthy computational formulas, and the derivation process is quite complicated, requiring a good mathematical foundation to learn well. Limited by the teaching duration, although many algorithms have been explained in detail, there is relatively insufficient practical guidance. Students find it difficult to intuitively understand, leading to issues like some students disliking the course and poor teaching effectiveness.

(2) Imbalance between learning and application. Currently, most courses related to computational methods are only directed at second-year undergraduates. Students rarely encounter specific engineering problems and do not yet possess the ability to apply the knowledge they have learned to practical engineering. This leads to a complete lack of concept about the engineering significance and role of computational methods. There is a lack of interest and motivation to learn, and the impression of the learned content is not deep, which is easily forgotten, resulting in poor outcomes.

2. Current Teaching Situation

The new engineering computational Methods is a course offered during the foundational learning stage of our university students, including “Numerical Analysis”, “Numerical Computational Methods”, and “Computational Methods”. In terms of learning, students should not only master the methods and principles of numerical computation but also how to use computational tools to find the numerical solutions of mathematical problems [7,8] (or mathematical models).

Under the new engineering background, through the computational methods course, we hope to train students to apply mathematical and other professional knowledge to solve complex engineering problems; use the basic principles of mathematics to analyze complex engineering problems; have the ability to apply basic engineering knowledge and computer knowledge to solve the mathematical models of specific objects; be able to select research plans based on the characteristics of the objects and construct computational models according to the experimental plan, safely carry out experiments, and correctly collect experimental data; recognize the necessity of continuous exploration and learning, and have the awareness of autonomous learning and lifelong learning.

Taking this as an opportunity, the course group has reformed the course teaching content, teaching methods, and teaching means. According to the new training program, a targeted teaching syllabus and teaching plan for this course have been formulated. Since 2016, the course group has localized the computational methods, compiled the textbooks “Numerical Analysis” and “Numerical Computational Methods” as well as “Computational Methods Study Guide”, constructed new teaching content, recorded online learning resources, and the course reform has achieved results. Figure 1 is a statistical graph of the number of students each academic year from 2014 to 2022. It can be seen that the number of course enrollees is increasing year by year and maintains more than 300 students each academic year.

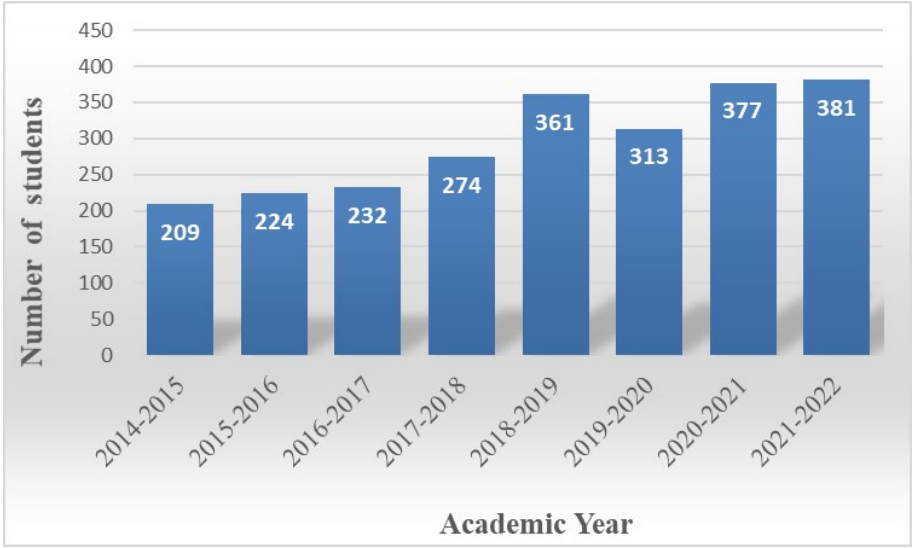

Figure 1: Number of students attending classes per academic year.

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In summary, although we have achieved preliminary results in the teaching of computational methods, there are still deficiencies in cultivating students' abilities. We are still using the traditional teaching model of "pre-study, explanation, review, and examination". This project is based on the implementation of the University Mathematics Teaching Research and Development Center projects "Research on the Application of High-Quality University Mathematics Course Resources in Teaching" and "Research on University Mathematics Teaching Modes and Methods for New Engineering in an Online Resource Environment". Relying on the online teaching platform of the Higher Education Press, we will conduct a blended teaching reform study on the computational methods courses of some engineering majors at our university based on the OBE education concept. We will explore and practice teaching design, teaching mode, resource construction, and teaching feedback in blended teaching, and provide specific teaching implementation plans and teaching cases. This enables students to deeply understand the knowledge they have learned in the process of proposing, analyzing, and solving problems, from the ability to think independently and cooperate in teams, and thereby cultivate students' innovative abilities.

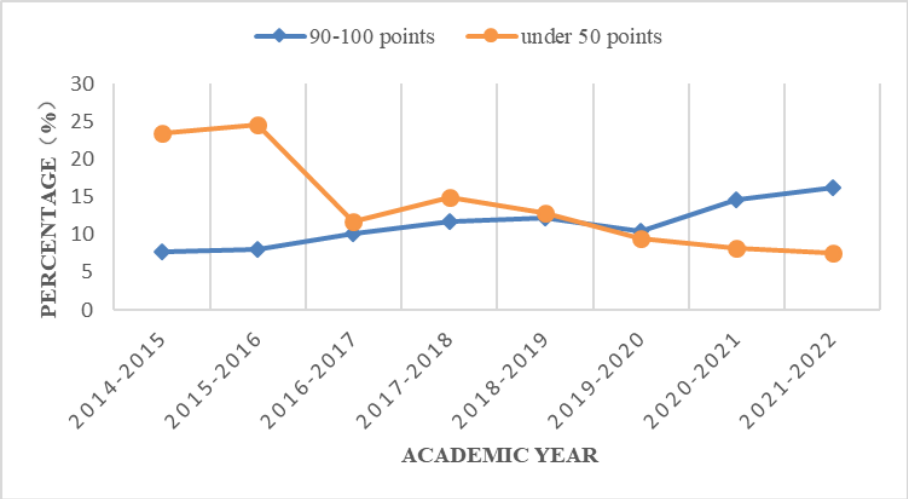

Figure 2: Changes in the proportion of high scores (⩾90) and low scores (⩽50).

Figure 2 presents the analysis of grades for each academic year, and the data shows that the percentage of scores between 90-100 has gradually increased from 7.66% in 2014 to 16.27% in 2022, nearly doubling. At the same time, the percentage of scores below 50 has decreased from 24.44% in 2014 to 7.61% in 2022, which is a decrease of 30% compared to 2014.

3. "Online and Offline" Blended Teaching Model

Based on the OBE educational concept, this course explores the design of a blended teaching model for computational methods courses that center on students, both online and offline. We select teaching resources suitable for the characteristics of our school's informatization from high-quality course resources, and optimize and integrate them into teaching units suitable for basic student learning. We implement blended teaching reform in stages during course teaching. As shown in Figure 3, we explore and practice corresponding teaching methods in the three teaching stages of pre-class preparation, in-class teaching, and post-class consolidation. We organically integrate high-quality online course resources with classroom teaching, implementing a blended teaching reform of "online active learning + offline interactive discussion".

(1) Outcome-Oriented Method Design

Outcome-oriented methods focus on students' learning outcomes and require the entire teaching process to serve the achievement of these outcomes. The teaching objectives of the course should cover the outcomes to be achieved, based on the training objectives and graduation requirements of the new engineering majors. In our teaching model, we have designed outcome output as teaching objectives to support graduation requirements, and provided implementation methods, as shown in Table 1. The achievement of all ability output objectives is problem-based. Students cultivate ability requirements, construct ability levels, and ultimately achieve ability outputs in the teaching process of solving problems.

(2) Design of Online and Offline Blended Teaching

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The blended teaching model requires the integration of high-quality online resources (the resources are shown in Figure 4). Students make full use of these integrated resources to carry out online pre-class preparation, blended classroom teaching both online and offline, as well as online post-class consolidation. Through scenario introduction, interactive communication, class summary, evaluation and reflection, students are encouraged to explore issues independently, understand and apply their learning, thus enhancing their interest in learning and improving their problem-solving abilities.

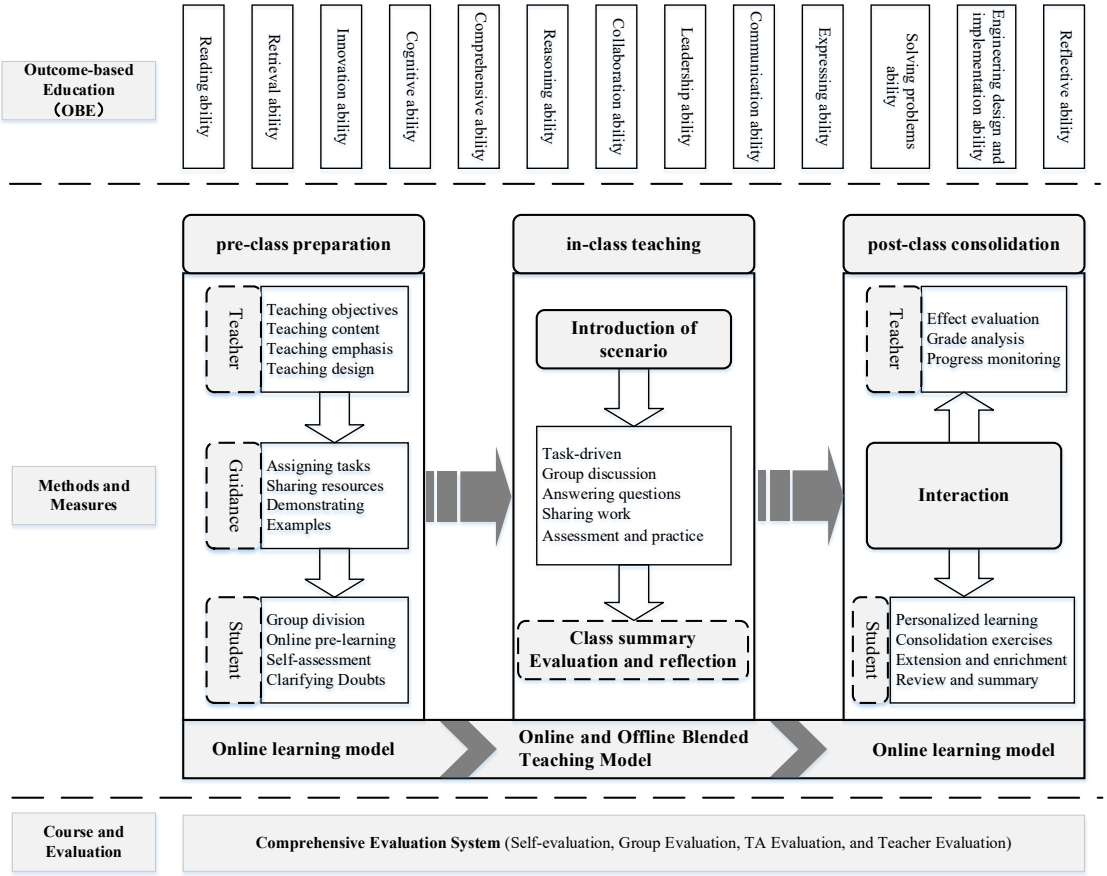

Figure 3: The research content of blended teaching in the new engineering discipline of computational methods based on the OBE concept.

Table 1: Support of ability output objectives for graduation requirements.

Course Teaching Objectives	Measures and Methods	Support for Graduation Requirements
Cognitive Ability	Textbooks and Materials	Engineering Knowledge
Analytical Ability	Analysis and Discussion	Problem Analysis
Retrieval Ability	Utilization of Network Resources	Use of Modern Tools
Cooperation, Leadership Ability	Team Organization, Exploration	Individual and Team
Communication, Expression Ability	Discussion, Research, Speech	Communication and Expression
Ability to Design Problems	Designing New Problems	Innovation, Lifelong Learning
Interpersonal Ability	Group Cooperation, Teacher-Student Communication	Humanistic Literacy and Morality
Problem Solving Ability	Completing Problem Solving	Designing Solutions
Engineering Design Ability	Solving Complex Problems	Engineering and Society, Project Management
Reflective Ability	Comprehensive Evaluation System	Reflection

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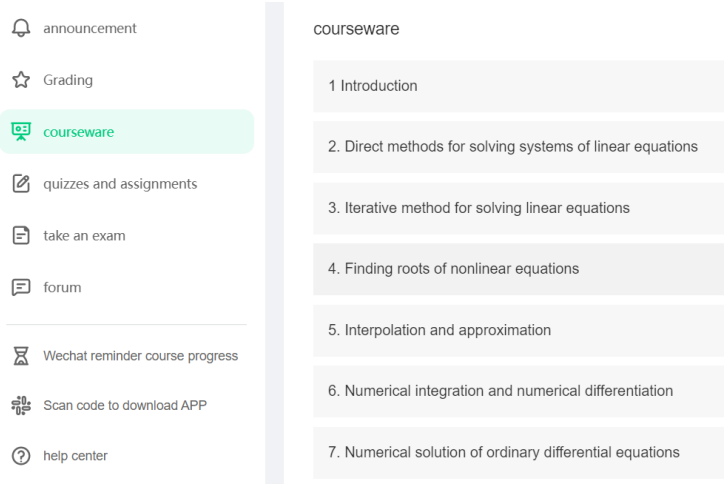

Figure 4: Online resources for computational methods.

(3) Exploring Blended Teaching Approaches

The blended teaching reform for the computational methods course adopts a four-stage teaching model of "preparation - classroom - review - innovation". The entire process is outcome-oriented, and different learning tasks are designed for each stage. The teaching process is arranged in a logical sequence of "pre-class self-study - classroom teaching - post-class extension - innovative application", aiming to achieve the ability output objectives through the completion of these learning tasks. Pre-class self-study includes independent learning using recommended course resources and instructional videos on the ICC platform. It also involves targeted pre-class exercises, identifying specific questions to explore, and referring to exemplary cases.

Classroom teaching involves setting up and conducting classroom activities. It combines selected high-quality course videos to organize student-led discussions, question generation between teachers and students, collaborative group learning and exploration, showcasing student applications, testing and feedback, as well as teacher reviews and summaries.

Post-class extension includes platform discussions, assignment feedback, understanding the frontiers of the discipline, model analysis, application guidance, etc. Students are guided to summarize the classroom content based on the difficulty level of the teaching materials, in order to expand their knowledge system of computational methods.

Innovative application is problem-driven. Students are trained to provide multiple solutions for the same problem, fostering divergent thinking, associative thinking, and other cognitive skills. This process cultivates students' ability to independently construct new knowledge, ideas, and methods for innovative applications.

(4) Establishing a Comprehensive Evaluation System

Based on the conception and design of this project, and considering the characteristics of the course and the requirements of teaching implementation, a comprehensive evaluation system is established, combining individual assessment with group assessment, as well as teacher evaluation with student peer evaluation. The evaluation system includes four indicators: self-evaluation, group evaluation, teaching assistant evaluation, and teacher evaluation, along with several related evaluation criteria. The assessment proportions for each level of indicators have been designed. Table 2 presents the comprehensive evaluation system and the breakdown of indicators designed by the course group.

4. Teaching Case Studies

To embody the guiding principles of teacher-led instruction and student-centered learning, the teaching content is decomposed into "preparation, classroom teaching, post-class extension, and innovative application" stages. Based on the logical relationships between knowledge points, the units of knowledge are further refined. The design reflects teaching requirements, key difficult points, and teaching objectives. Moreover, diverse teaching resources are provided to facilitate a variety of teaching activities. Taking "Numerical Methods for Solving Linear Systems" as an example, the implementation of blended teaching is presented in Table 3.

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Table 2: Comprehensive evaluation system.

Evaluation Indicators	Percentage (%)	Assessment Content
Self-evaluation	30	Learning attitude, sense of achievement
Group evaluation	30	Participation, contribution, communication and performance
Teaching assistant evaluation	20	Learning attitude, effort, execution ability
Teacher evaluation	20	Passion for the subject, character development, study planning

Table 3: Implementation Case Study of Solving Linear Systems.

Teaching Stage	Teaching Objectives	Teaching Methods	Teaching Activities	Teaching Evaluation
Pre-class self-study	Understand direct methods and iterative methods	(1) The teacher publishes pre-class assignments on the platform (2) Students engage in online pre-class study	(1) The teacher publishes tasks, shares instructional videos, and provides self-assessment exercises (2) Students watch pre-learning videos and complete pre-class self-assessment exercises	(1) Online learning data statistics (2) Test reports
In-class teaching	Understanding the different representations and reasons for finding numerical solutions to linear systems.	Knowledge Introduction	(1) Lecture: Summarize the different representations (2) Discussion: Explore the essence and significance of various representation forms	Participation in discussions
	Understanding the direct method and the problems associated with the direct method	(1) Teacher explanation (2) Group discussion (3) Experimental demonstration (4) Teacher summary	(1) Divide into small groups to discuss the direct method (2) Present the process and pros and cons of using the direct method (3) Summarize the advantages and issues	(1) Degree of participation in the discussion (2) Accuracy of answering questions
	Understanding and mastering several iterative methods for finding numerical solutions to linear systems of equations.	(1) Teacher instruction (2) Experimental demonstration (3) Classroom exercises (4) Teacher summary	(1) Explain the derivation of iterative methods (2) Demonstrate the process of using iterative methods (3) Guide students to summarize the advantages and disadvantage	Accuracy in answering questions
	Understanding and mastering the convergence and error estimation of iterative methods	(1) Teacher explanation (2) Group discussion (3) Sharing of pre-learning case studies in groups (4) Teacher feedback and comments	Case analysis: (1) Different iterative formulas used for the same problem (2) Case analysis and discuss.	Participation in case analysis
Post-class extension	Mastering the direct method and iterative method, and being able to write code to implement these methods	(1) Teacher posts review tasks on the platform (2) Students review and practice	(1) The teacher posts review tasks, additional materials, and post-test questions (2) Students watch preview videos and complete self-test	(1) Online learning data statistics by students (2) Review test reports.
Innovative application	To address problems in engineering practice	Group information retrieval	group presentation	participation in report writing and presentation

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The case study focuses on student-centered learning and integrates online resources. It adopts various teaching methods such as lecture-style, discussion-based, and flipped classroom approaches to implement blended teaching for the topic of "Numerical Methods for Solving Linear Systems." It aims to inspire students to think actively, encourage their participation in discussions and interactions, leverage their individual strengths, transform their passive learning into active engagement, break the silence in the classroom, and create a dynamic learning environment.

The Rain Classroom platform is utilized for in-class exercises and assessments. Based on the results of the tests, the teacher can evaluate students' understanding of the knowledge and organize group discussions or group presentations accordingly. By using open-ended questions as prompts, students are encouraged to deeply comprehend the teaching content and quickly grasp the key points. Through case studies, students will acquire essential computational skills and enhance their ability to apply learned knowledge to solve practical problems.

5. Conclusion

The course content of "Computational Methods" is extensive, with abstract algorithms and complex formulas. In response to the training objectives of the computational methods course in the context of the new engineering disciplines, we have explored the blended teaching reform of computational methods from several aspects, such as teaching design, teaching methods, resource development, and teaching feedback, drawing on the OBE concept. This has helped bridge the gap between teaching and learning. The course serves a large number of students and continuously stimulates their interest in learning. It emphasizes self-directed learning, the integration of theory and practice, and the continuous improvement of algorithms to enhance problem-solving abilities for real-world applications. The ultimate goal is to cultivate applied talents with strong theoretical and practical skills. However, several issues should be noted for continuous improvement of the course. Firstly, the case-based teaching method should focus on student-centered learning, with the role of the teacher being to organize and guide. Secondly, in the process of case analysis, it is important to ensure the "openness" of case-based teaching and provide positive encouragement and affirmation to students' thoughts.

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