

Research on the Teaching Design of Advanced Mathematics Courses Based on Outcome-Based Education Concept

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Abstract: This paper first analyzes the characteristics and current situation of the Advanced Mathematics course; secondly, it proposes a teaching model that integrates the outcome-based education (OBE) philosophy and blended teaching method, reorganizing the teaching objectives, teaching content, and assessment evaluation process of the Advanced Mathematics course; lastly, through practice, it is proved that this approach can effectively improve students' mastery of course content, enhance students' ability to apply mathematical knowledge, and strengthen teaching effectiveness.

Keywords: Advanced Mathematics; Outcome-based education concept; Blended teaching method

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1. Introduction

Advanced Mathematics is a basic course required for non-mathematical undergraduate majors. It serves as a tool course for learning knowledge related to various professional courses and as a practical course for training mathematical thinking and methods. The traditional Advanced Mathematics classroom has problems such as a one-way teaching model, disconnection between theory and practical application, lack of personalized teaching, and a single evaluation method^[1]. Therefore, the research group based on the three major educational concepts of outcome-based education (OBE)—centered on students, problem-oriented, continuous improvement—formulated course teaching objectives, infused “Internet+” thinking, and carried out a blended teaching mode that integrates online and offline, in-class and out-class. We can achieve this by fully utilizing rich teaching resources such as massive open online courses, learning platforms, or Rain Classroom, creating a learning environment that is autonomous, cooperative, and exploratory, achieving connectivity between online and offline, in-class and out-class; establishing a deep learning model, following the constructivist learning view, making abstract problems concrete, focusing on the experiential process of knowledge formation, highlighting the student's active role in learning; integrating course ideology with professional characteristics, emphasizing the value-guiding function; conducting diversified assessments, guiding students to think and discuss actively, and achieving the transformation from “I have to learn” to “I want to learn.”

The teaching of Advanced Mathematics not only needs to clarify “what mathematics is” but also to explore the questions of “where mathematics comes from” and “why.” It is not only about “teaching,” but also about “teaching thoroughly” and “teaching actively.” In addition to learning knowledge, what is more important for students is the learning of cognitive strategies and thinking methods, mastering the thinking of mathematics, and ultimately learning to study independently. This article focuses on the teaching outline and talent training objectives, using modern educational methods, innovative teaching methods, and conducting online blended teaching. We need to reasonably utilize various forms of classroom teaching activities such as lectures, group discussions, and flipped classrooms to ensure that students have enough time for autonomous learning and training, use information technology teaching methods, reform assessment methods, conduct timely classroom assessments and online unit tests, strengthen the timeliness and effectiveness of formative assessments, and constantly improve teaching effectiveness.

2. The design of teaching Advanced Mathematics under the concept of OBE

2.1. Teaching objective design

OBE is an educational philosophy and model that emphasizes the ultimate outcome of teaching activities, which is the learning outcomes of students. Its core idea is to place the expected learning outcomes that students can achieve at the center of education, rather than focusing on traditional teaching content or processes. Based on the OBE educational philosophy, the design of curriculum and teaching starts with the design of teaching objectives^[2]. According to the OBE educational philosophy, the principles of curriculum and teaching objectives design are based on graduation requirements, course characteristics, and content systems to determine learning outcomes and to provide detailed guidance for subsequent learning activities. Following this design principle, the goal is to design objectives oriented towards students’ learning outcomes, achieving curriculum and teaching objectives on the three levels of “knowledge imparting, skill development, and value guidance.” In the cognitive domain, lower-level teaching objectives are set as students achieving “knowledge, understanding, application,” and higher-level teaching objectives are set as achieving “analysis, synthesis, and evaluation.” In terms of ability development, the goal is to improve the ability to analyze and solve problems using the values of disciplines and courses. In terms of value objectives, the goal is to shape students’ worldviews, life philosophies, and values.

To refine the implementation of course teaching objectives, the course teaching objectives are divided into knowledge objectives, skill objectives, and value objectives.

- (1) Knowledge objectives: Through the study of this course, students are expected to acquire the basic concepts, basic theories, and basic operational skills in functions and limits, single-variable calculus, vector algebra and spatial analytic geometry, multivariable calculus, infinite series, differential equations, etc., laying the necessary mathematical foundation for subsequent courses and further acquisition of mathematical knowledge.
- (2) Skill objectives: While imparting knowledge, it is important to gradually enhance students’ skills in abstract thinking, logical reasoning, spatial imagination, computational skills, and self-learning abilities through various teaching activities. Special attention should also be paid to cultivating students’ skills to comprehensively apply the knowledge they have learned to analyze and solve problems.
- (3) Value objectives: Taking knowledge as the medium and classroom activities as the main battlefield, while guiding the cultivation of mathematical cultural values, the curriculum aims to cultivate students’ serious attitude towards work, scientific and rational spirit, tenacious exploratory spirit, fearless character in the face of difficulties, and perfect and harmonious personality.

2.2. Teaching mode design

“What kind of people to train,” “how to train people,” and “who to train people for?” are the fundamental problems of talent training. OBE education concept provides an overall idea of talent training and targets the results of education. The OBE concept emphasizes the output of learning results, which subverts the traditional teaching concept of teaching materials. As a new type of teaching mode, the flipped classroom is a “destructive innovation” of the traditional teaching mode. It is a new educational mode under the background of the Internet, with the help of network resources and facilities. The flipped classroom based on the OBE concept requires teachers to release students’ expected learning results, task lists, and evaluation rules based on the online teaching platform, and widely apply task-driven, problem-oriented, case presentations, and other methods to conduct effective teacher-student interaction, so as to fully mobilize students’ enthusiasm and autonomy in learning. The innovative points of flipped classroom teaching based on OBE lie in, firstly, the master of classroom activities is changed from teachers to students; secondly, teachers rely on teaching platforms to organize learning results through project-led and task-driven methods, and guide students to carry out online learning through independent learning, cooperative learning, and inquiry learning. In this way, with results-oriented teaching combined with the flipped classroom teaching mode, students can more clearly understand “what I should learn” and truly improve the phenomenon of “two skins” in teaching.

Before class, students are motivated to develop their interest in learning, build a preliminary knowledge framework, and clarify learning objectives by watching videos, participating in online discussions, asking questions, and taking knowledge and skill assessments. In class, students are the focus, and teaching is integrated in a task-driven manner to promote the internalization of knowledge, knowledge application, and skill development. After class, students are guided to complete assignments and extension tasks on the learning platform to further strengthen their ability to apply knowledge and engage in innovative practices.

2.3. Building deep learning models

The concept of deep learning in the field of education was first explicitly proposed in 1976 by American scholars in “The Natural Distinction of Learning: Outcome and Process”^[3]. Deep learning is a learning process that accompanies knowledge transfer, is active and highly engaging, and involves high-order thinking. Deep learning refers to a meaningful learning process in which students, guided by teachers, focus on challenging topics, actively participate wholeheartedly, experience success, and achieve development. Deep teaching emphasizes valuing students’ rich experiences in the learning process, focusing on cultivating students’ high-order thinking, and ultimately enabling students to learn and think independently.

Czech famous educator Comenius^[4] pointed out that people’s learning of knowledge is achieved by combining senses and imagination. Especially for natural sciences like mathematics, in the teaching process, teachers’ task is not just to transfer the predetermined knowledge to students step by step, but to create certain situations for students’ learning activities, allowing students to actively construct knowledge through exploration and problem-solving, and gradually master mathematical methods and skills in a well-designed practical process.

Based on the OBE educational concept, following the theories of deep learning and constructivist learning, the cognitive process of deep learning in mathematics can be divided into six stages: motivation stage, preparation stage, modeling stage, abstracting overview, revealing essence, and application and innovation^[5]. Specific processes are shown in **Table 1**.

Table 1. Deep learning model

Cognitive stage	Teaching strategies
Motivation stage	Teachers inspire students to think by constructing situational problems and stimulating learning motivation.
Preparation stage	Teachers guide students to establish links with existing knowledge, activate previous knowledge and experiences, and provide a theoretical basis for learning new knowledge.
Modeling stage	Teachers analyze the problem, simplify assumptions, and establish mathematical models.
Abstracting overview	Teachers abstract mathematical concepts by decontextualization.
Revealing essence	Teachers establish connections with existing knowledge, reveal the mathematical essence, deepen the understanding of concepts, and achieve long-term memory retention.
Application and innovation	Teachers recall and extract knowledge information stored in memory systems during problem-solving and learning of new knowledge, in order to establish logical connections with new knowledge and promote the reconstruction and creative application of existing knowledge in practice.

2.4. Exploring professional course ideological and political cases and highlighting the leading value

The course of Advanced Mathematics not only contains abstract mathematical knowledge but also rich cultural resources and historical origins, with powerful educational functions for guiding the values of students. “Student-centered” is the latest concept in the development of higher education worldwide. The course design of Advanced Mathematics should be carried out around the teaching model of “student-centered,” creating more learning space for students, guiding students to think independently, learning to analyze and solve problems with correct positions, viewpoints, and methods, establishing dialectical thinking and innovative thinking, highlighting the student’s subject position. In order to achieve this goal, we delve into the ideological and political elements contained in the course content, incorporate the design of ideological and political education into the syllabus and lesson plans, cultivate students’ patriotism, scientific literacy, innovative spirit, and dialectical thinking through online resource development and offline teaching activities. In terms of resource development, ideological and political cases are produced in the forms of documents, videos, multimedia courseware, etc., and uploaded to the online teaching platform. For example, presenting mathematical inspirational culture in the resource library allows students to appreciate the hardships of scientific research and the indomitable will of scientists.

In the process of teaching organization, combining the characteristics of disciplines and majors to design a collection of course-related ideological and political cases and closely integrating mathematical knowledge and professional knowledge allow students to not only recognize the significance of learning mathematical knowledge but also subconsciously engage in professional education, enhancing students’ interest in learning. For example, when teaching the concept of the limit of sequences to first-year students majoring in e-commerce, relevant compound interest cases are introduced to warn students to stay away from campus loans, resist hedonism, and cultivate the habit of rational consumption. When teaching the concept of definite integrals to students majoring in architecture, examples related to the Three Gorges Project spillway cross-sectional area and the area of the Anhui map are chosen to cultivate students’ ability to solve practical problems and innovation consciousness.

The diverse teaching activities enable students to realize that the connotation of ideological and political education is inseparable from mathematical knowledge. The rigorous and conscientious academic attitude of teachers and their exemplary personal charm also influence students. The teachers’ dedication to educating students makes ordinary mathematics classes warmer and more welcoming.

2.5. Implementing diversified teaching assessment

The teaching principle of results-oriented education is that “teaching is about learning.” Adhering to the evaluation principle of “teaching based on learning,” that is, teaching effectiveness should be evaluated through learning effectiveness. Therefore, emphasis is placed on evaluation methods that focus on the process of achieving results, and assessment requirements track students’ ability progress. After teachers complete teaching activities, students’ learning outcomes are objectively and effectively evaluated through clear assessment indicators, with students’ learning attitude, learning behavior, learning ability, and learning outcomes as the core, to achieve diversified ways of assessing students’ learning performance.

The teaching implementation is mainly based on process assessment, combining formative assessment and summative assessment. Formative assessment consists of two parts: online and offline classrooms. Formative assessment based on online teaching platforms can objectively control students’ learning status. The evaluation process of online teaching mainly includes data and problem induction of pre-class independent learning feedback; data monitoring of student discussions, self-assessment, peer assessment, barrage comments, speeches, exchange, and voting during class; and post-class assignments, completion of chapter tests, discussion frequency after class, and evaluation frequency of achievements display. Objective data analysis and information feedback make students’ classroom evaluation more rational and improve the accuracy of evaluation. The formative assessment of offline classrooms includes students’ classroom learning behavior, participation in class, and completion of tasks. A thorough and objective formative assessment can help teachers grasp students’ learning status, understand students’ learning behaviors, and analyze students’ learning pain points. Summative assessment is generally conducted at the end of the teaching phase, guided by the OBE concept. Based on teaching evaluation, according to the degree of learning achievement, we can reflect on the reasons for students’ unsatisfactory learning outcomes, follow the principle of “continuous improvement,” reconstruct teaching design, content, and strategies to enhance the high-level, innovative, and challenging nature of classroom teaching.

3. Typical cases

The concept of definite integral in Chapter Five, Section One of the Advanced Mathematics course is taken as an example.

3.1. Pre-class preparation

Before class, the teacher posts self-study tasks and two discussion topics on the Learning Platform. (1) After watching the micro-lesson introducing the concept of definite integral, do you think it is possible to replace the area of trapezoids with the area of small curved trapezoids in the process of dividing them? (2) After watching the “method of cutting circles” flash animation, what mathematical idea do you understand? From the results submitted by students, 80% of them do not understand the idea of “approximating the curved with the straight, infinite approximation.” Therefore, this lesson includes the “five-step” teaching process: context introduction, concept analysis, method guide, extended thinking, and application promotion.

3.2. In-class studying

3.2.1. Context introduction

Topic discussion on e-learning: The use of the words “accumulate” or “points” in everyday life. Following this, the cross-section of the overflow dam and the map of Anhui are displayed. Students observe the images and think about how to calculate the area of irregular shapes.

3.2.2. Concept analysis

Firstly, students watch the “Method of Exhaustion” to experience the mathematical idea of “approximating curves with straight lines.” Analogous to the “Method of Exhaustion,” they think about how to calculate the area of a trapezoid with curved sides. Teachers guide students to apply the mathematical idea of “approximating curves with straight lines” to find the area of a trapezoid with curved sides, thus abstracting, generalizing, and summarizing the concept of definite integral.

3.2.3. Method guide

Teachers provide the geometric interpretation of the definite integral by its definition, guiding students to compute the cross-sectional area of an overflow dam and the area of a map. Students are encouraged to actively engage in thinking, deepen their understanding of the concept of definite integral, and reinforce the application of definite integrals.

3.2.4. Extended thinking

Teachers assign tasks on the teaching platform: To calculate the distance of variable speed linear motion. Students work in groups to complete the task and upload the results to the teaching platform; share and showcase homework, explore layer by layer, and activate students’ thinking.

3.2.5. Application promotion

Students and teachers collaborate to summarize and organize the applications of definite integrals in geometry and physics, such as calculating area on a map, work done by variable forces, distance of uniform accelerated linear motion, and moment of inertia.

3.3. Post-class improvement

After class, students are required to log in to the learning platform to complete an online test; focusing on solving real problems with definite integrals, a practical case has been arranged—calculating the area of the lawn on our campus. This task requires students to work in groups to measure the dimensions of the lawn after class, then calculate the area of the lawn, and finally upload it to the learning platform in the form of a short paper. Other students will watch it and give ratings.

4. Conclusion

Through the promotion of curriculum innovation and reform, the classroom has become more enriched and livelier. Students enjoy higher mathematics courses now and are more willing to communicate with teachers. The number of students actively participating in interactive classroom activities is increasing. The enthusiasm and initiative for learning have significantly improved. Students are obviously more careful and serious about their homework than before, and their mid-term and final exam scores have also improved significantly. At present, teaching innovation still needs further improvement. In the future, it will be promoted in the form of a team in all university mathematics courses in the school, benefiting more students from teaching reform and innovation. In the classroom, “whetting the appetite” is used instead of “feeding,” leading to a shift from traditional classrooms to smart classrooms, knowledge-oriented classrooms to ability-oriented classrooms, rote learning classrooms to practical classrooms, and closed classrooms to open classrooms.

Disclosure statement

The author declares no conflict of interest.

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