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Exploration of Cultivating Students' Innovative Thinking Ability in University Mathematics Teaching

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Abstract: Against the backdrop of the development of emerging engineering education and the high-quality advancement of higher education, cultivating innovative talents has become an important objective of curriculum reform in universities. As a fundamental course for science and engineering education, university mathematics plays an irreplaceable role in the training of students' logical thinking, the improvement of problem-analysis abilities, and the development of innovative awareness. In response to the existing problems in university mathematics teaching, such as relatively single teaching models, insufficient integration of theory and practice, and weak student learning initiative, this study is based on the teaching practice of university mathematics courses and explores multiple aspects, including the cultivation of mathematical literacy, the reform of teaching methods, the optimization of teaching content, the construction of information-based teaching platforms, and the establishment of diversified evaluation mechanisms. Teaching practice shows that through the implementation of student-centered teaching reform, combined with problem-based teaching, case-based teaching, flipped classrooms, mathematical modeling, and blended online-offline instruction, students' interest in learning can be effectively stimulated, their awareness of mathematical applications can be strengthened, and their autonomous learning ability, innovative thinking ability, and comprehensive ability to solve complex practical problems can be significantly improved. The findings of this study may provide useful references for the reform of university mathematics teaching and the cultivation of innovative talents.

1. Introduction

Cultivating new-generation talents with innovative spirit and creative ability has become a major focus of higher education reform in China. One of the key factors determining the quality of talent cultivation is curriculum design. Mathematics courses serve as the foundation of natural sciences and also as the cornerstone of major technological innovation and development. Mathematics-related courses play an essential supporting role in talent cultivation and are of great significance in improving students' mathematical literacy and enhancing innovative thinking. Mastering solid knowledge of advanced mathematics not only helps students establish correct values and improve

their mathematical literacy, but also fosters their scientific research awareness, innovative spirit, and problem-solving abilities [1, 2].

The university mathematics curriculum system for non-mathematics majors in science and engineering institutions mainly includes compulsory courses such as Advanced Mathematics, Linear Algebra, and Probability Theory and Mathematical Statistics, as well as elective courses such as Mathematical Modeling and Mathematical Experiments. These courses are relatively independent while also being closely interconnected. Through the study of mathematics courses, students can develop preliminary mathematical thinking, master fundamental mathematical knowledge, train their mathematical thinking abilities, and apply mathematical knowledge and methods to solve theoretical problems. Furthermore, they can apply mathematical perspectives to understand and describe objective phenomena, thereby supporting scientific and technological innovation. In the face of a new round of global scientific and technological revolution, how to improve students' mathematical literacy in university mathematics teaching has become an important issue in current curriculum reform [3].

How to improve the teaching quality of university mathematics courses, enable students to effectively master basic concepts and fundamental knowledge, and cultivate and enhance students' logical thinking ability, mathematical modeling ability, and innovative practical ability in mathematics learning has become an important topic in the reform of mathematics education in higher education institutions.

2. Enhancing Students' Mathematical Literacy and Mathematical Thinking

Mathematical literacy can generally be understood as students' ability and tendency to observe, analyze, and solve problems using mathematical perspectives, mathematical thinking, and mathematical methods. In today's educational context, the development of individual core competencies has become a major educational theme worldwide, and mathematical literacy is an important component of core competencies. Therefore, the development of students' mathematical literacy has become one of the important directions in education. Teaching practice must attach great importance to the cultivation of students' mathematical literacy.

Learning motivation plays a decisive role in students' learning behavior. In mathematics teaching, efforts should be made to stimulate students' positive learning orientation, awaken their sense of subjectivity, and enhance their motivation for learning [4,5]. First, teaching content should be closely connected with the broader context of national economic and social development, helping students better understand the country's macro-development strategies and stimulating their enthusiasm for learning in support of national rejuvenation. Second, teaching content should be closely integrated with students' majors, enabling them to recognize the instrumental and technical significance of university mathematics in professional learning and practice, thereby increasing their attention to mathematics learning. The close integration of knowledge and practice, along with the selection of topics relevant to students' interests, helps students recognize the social value of learning and strengthens their intrinsic learning motivation. At the same time, modern scientific methods and introductions to frontier mathematical theories should be incorporated as much as possible to meet students' desire for novelty, change, knowledge, and practicality.

It is also essential to cultivate students' mathematical thinking and awareness of quantitative analysis based on data. According to modern mathematical methodology, mathematics learning is essentially a cognitive activity, which plays a unique and significant role in training and improving thinking ability. Therefore, cultivating students' mathematical thinking as well as their awareness and ability to think quantitatively through data analysis is an important objective of mathematics education. While imparting key disciplinary knowledge, teachers should also develop students'

computational ability, logical reasoning ability, and analytical ability. More importantly, students should be guided to integrate learning, conjecturing, questioning, proving, thinking, and hands-on practice, deeply explore the thinking methods and cognitive processes embedded in the theoretical system of mathematics, enhance their mathematical perspectives, and gradually develop the awareness and ability to use data for evidence-based reasoning and quantitative problem-solving. Through the cultivation of mathematical awareness, students can further develop the habit of applying mathematical tools, computational software, and analytical methods to summarize, analyze, and solve practical mathematical problems, thereby forming a mathematical way of thinking.

3. Reforming Teaching Methods and Teaching Content to Strengthen Practice and Application

3.1. Improving Teaching Methods

It is necessary to innovate teaching models, transform traditional teacher-centered instructional methods and organizational forms, and gradually shift toward a student-centered teaching model [6]. Traditional education has often placed excessive emphasis on the dominant role of teachers in the instructional process while neglecting students' initiative and subjectivity, which is not conducive to the cultivation of innovative thinking. Following the principle of serving students' development, various approaches, such as the flipped classroom, can be adopted to reconstruct teaching organization and fully develop students' learning ability in classroom.

In classroom instruction, problem-oriented teaching methods can be effectively applied. During the teaching process, instructors may raise thought-provoking questions to encourage students to analyze, investigate, and discuss, guiding them through the process of "discovering problems—posing problems—analyzing problems—solving problems—discovering new problems—and ultimately solving problems". By fully embodying the guiding role of teachers and the central role of students, students' initiative and enthusiasm can be enhanced through active participation and collaborative discussion, thereby increasing their interest in learning and strengthening their ability to comprehensively analyze and solve practical problems. Emphasis should be placed on introducing new topics through practical problem-solving contexts. Problem-oriented teaching focuses on shifting the teacher's role from knowledge transmission to facilitating students' problem-solving abilities. By guiding students to face real-world problems and challenges, teachers encourage them to explore, analyze, and solve problems independently. This learning approach emphasizes students' autonomy and cooperation, requiring them to explore the knowledge and skills behind problems.

The case teaching method is also highly applicable to university mathematics instruction [7]. Case-based teaching offers many advantages. In practical teaching, real-life problems can be introduced to establish mathematical models, allowing students to discuss abstract mathematical problems derived from real situations, form their own insights, and deepen their understanding and application of knowledge points. From the perspective of pedagogy, the focus of case teaching lies in the development of students' creative thinking and practical problem-solving abilities, rather than merely acquiring fixed principles and formulas. Mathematics is an applied discipline, and by designing practical examples during instruction, teachers can help students better understand mathematical concepts and theories, stimulate active learning, and improve students' application abilities.

Flipped teaching has emerged in recent years as an important student-centered instructional approach for cultivating cognitive abilities and innovative thinking [8,9]. According to specific

teaching content, appropriate chapters can be selected and designed for flipped teaching implementation. Teachers should actively transform their teaching concepts and attempt to introduce the flipped classroom model into university mathematics instruction. The flipped classroom not only breaks the temporal and spatial constraints of traditional teaching, but also emphasizes students' subjectivity and participation, providing a more flexible and personalized learning environment. To successfully implement this model, teachers need to deeply understand the core concepts of the flipped classroom, master its instructional design and implementation strategies, design engaging learning tasks, and effectively guide classroom discussion and collaborative learning. At the same time, teachers should continuously reflect on and adjust their teaching practices to adapt to the new challenges and opportunities brought by this teaching model.

As a new student-centered instructional model, the flipped classroom can effectively overcome the time and space limitations of traditional teaching. By designing pre-class learning tasks, in-class collaborative discussions, and post-class reflection and evaluation activities, teachers can guide students to shift from passive reception of knowledge to active knowledge construction, thereby further enhancing their autonomous learning ability and innovative thinking.

3.2. Improving Teaching Content

When teaching course content, instructors should focus on cultivating students' mathematical thinking, logical reasoning ability, and innovative awareness, while improving their comprehensive abilities in analyzing and solving problems. Through modular curriculum design, course content can be optimized to enhance both practicality and relevance to contemporary developments. Based on traditional teaching materials, practical mathematical analysis cases closely related to current social and technological contexts can be introduced, helping students better understand the application of advanced mathematics in the real world. According to the teaching system, course content can be divided into general knowledge modules, professional demand modules, and practical application modules.

Introducing frontier academic achievements can ensure continuous innovation in course content. By incorporating important mathematical research findings from recent years into teaching, students can be introduced to cutting-edge academic developments and research methodologies, thereby enriching course content, broadening their academic perspectives, and enhancing their research and innovation capabilities.

How to integrate the content of university mathematics courses with practical problem-solving in order to achieve innovation in practice is an issue that every instructor should consider and address. Mathematical modeling can be introduced into teaching, using mathematical language and methods to abstract and simplify real-world problems into mathematical structures, which can then be solved using mathematical techniques. For example, when teaching Applications of Differential Equations, the optimization of logistics distribution routes can be introduced as a case study, guiding students to establish mathematical models to analyze the relationship between distribution costs and route selection. Through group discussion, model construction, and computational verification, students not only deepen their understanding of theoretical knowledge, but also improve their ability to use mathematical tools to solve practical problems. By integrating theory with practice, students can better understand and master the content of university mathematics courses while becoming familiar with the application of mathematical thinking in real-life situations, thereby realizing the importance of combining theory with practice.

In recent years, national mathematical modeling competitions for college students have been developing rapidly. Teachers can integrate modeling concepts into classroom teaching, connect basic knowledge with practical applications, stimulate students' interest, and encourage them to

actively participate in mathematical modeling competitions. This can cultivate students' ability to analyze and solve practical problems through mathematical modeling and significantly improve their innovative thinking abilities.

In addition to mathematical knowledge, teachers may also introduce the history of mathematics and mathematical culture into the curriculum to enrich course content and help students understand knowledge from multiple dimensions, thereby building a more comprehensive and multidimensional knowledge framework. Modular curriculum design, the introduction of frontier mathematical research achievements, and problem-solving-oriented teaching practice represent important innovations in teaching content, which can deepen students' understanding and application of mathematical knowledge and significantly enhance their innovative thinking abilities.

4. Constructing Information-Based Teaching Platforms to Expand the Time and Space of Mathematics Learning

At present, digital technology has opened up broad opportunities for innovation in higher education teaching, enabling students to engage in learning, interaction, and practice more efficiently [10, 11]. For example, online courses designed for university mathematics can provide comprehensive and multidimensional learning support resources, including online learning materials corresponding to textbook content, online question banks, and professional case collections. These resources enable students to acquire knowledge in a targeted manner and carry out autonomous learning. In addition, students can participate in online discussions and group collaboration, engage in mathematical modeling and simulation experiments, and apply mathematical knowledge to solve practical problems, thereby effectively improving their problem-solving abilities. Teachers can develop and utilize interactive online teaching platforms, carefully designing pre-class preparation, classroom review, after-class exercises, and other teaching activities. Through mechanisms such as learning check-ins and incentive rewards, students can gradually develop effective learning habits. By fully integrating classroom teaching with extracurricular learning, and organically combining knowledge acquisition, ability development, and practical application, the advantages of network-based education can be fully utilized to make teaching content broader, richer, and deeper. Classroom learning is only one pathway for students to acquire knowledge; outside the classroom, there is an even broader space for learning. More importantly, the ultimate goal of education lies in students' ability to effectively apply knowledge and develop innovative thinking.

In the process of university mathematics teaching reform, establishing online course platforms and constructing diversified resource databases can facilitate the three-dimensional integration of teaching resources. Through the innovation of blended online-offline teaching methods and instructional models, classroom teaching efficiency can be significantly improved. At the same time, a capability-development chain aligned with emerging engineering education can be established to promote the integration of curriculum content with competence development. A well-functioning, distinctive, and continuously updated online teaching platform can provide a multidimensional, information-based, and three-dimensional learning environment. Continuous efforts should be made to strengthen the construction of diversified resource databases and enrich digital teaching resources.

In the pre-class preparation stage, teachers can carefully select brief teaching cases, introduce the historical background of concepts, and provide simple practice exercises for students in advance. This helps students gain a preliminary understanding of the origins and applications of mathematical concepts while stimulating their enthusiasm and initiative in learning. Students can preview learning materials anytime and anywhere. If they encounter difficulties, they can raise questions through online communication tools or bring their questions to the classroom for

discussion. However, in order to avoid reducing students' motivation, the amount of pre-class learning material should be appropriately controlled. After distributing the preview materials, teachers should also promptly monitor students' completion status, remind students who fall behind, and evaluate subjective assignments submitted during preview activities. In the digital teaching environment, teachers can make use of the data collection functions of information-based teaching platforms to comprehensively obtain students' performance data in different learning stages and promptly understand their autonomous learning progress.

Through information-based teaching platforms, students can establish convenient communication channels with instructors. When students encounter difficult problems, they can simply send their questions to teachers and receive accurate and detailed explanations. Taking linear algebra teaching as an example, after learning the relatively abstract topic of elementary matrix transformations, some students may feel confused about the transformation principles. After receiving students' questions, instructors can begin with fundamental concepts and explain the essence of matrix transformations in accessible language, helping students understand the concept more clearly. This type of online tutoring has proven to be highly effective.

5. Constructing a Diversified Evaluation Mechanism to Promote the Development of Innovative Ability

Scientific and timely feedback and evaluation design are essential components in improving teaching quality. It is necessary to break away from static evaluation methods and construct a dynamic incentive-based evaluation mechanism that enhances motivation throughout the entire teaching process [12].

From the perspective of teaching evaluation, a comprehensive evaluation system combining formative assessment and summative assessment can be established based on the objectives of knowledge, ability, and literacy development. In teaching practice, the application of digital tools can greatly facilitate evaluation. For example, teachers can monitor students' learning progress and outcomes in real time through teaching platforms and provide timely feedback. Meanwhile, students can receive teachers' analytical evaluations and guidance on their assignments through the platform, or share creative ideas and learning experiences with peers, thereby helping them reflect more deeply on their learning processes and outcomes. Formative assessment plays a particularly important role. By utilizing information-based teaching platforms, teachers can use online tests and mind maps to assess students' mastery of mathematical knowledge and their application abilities. Traditional assessment methods that rely mainly on final examinations should be reformed by placing greater emphasis on continuous process evaluation, increasing the proportion of regular performance assessment, motivating students to participate actively, and guiding them to shift their focus from examination scores to the learning process itself, thereby cultivating good habits of autonomous learning.

A multidimensional assessment system integrating process evaluation, basic knowledge assessment, and practical innovation ability assessment can be established for university mathematics courses. Appropriately increasing the difficulty and depth of assessment can further promote the cultivation of innovative talents required by emerging engineering education. Specifically, process assessment may account for 30% of the total score, including attendance, classroom participation, homework completion, self-directed learning performance on online teaching platforms, chapter quizzes, self-assessment, and peer assessment. This requires teachers to set reasonable proportions and maintain complete assessment records. Basic knowledge assessment may account for 40%, evaluated through a closed-book final examination selected from the question bank. Practical innovation ability assessment may account for 30%, requiring students to complete a

mathematical application research report related to course content, such as mathematical computation methods or practical application strategies, thereby cultivating their ability to analyze and solve problems. Alternatively, teachers may provide extended mathematical modeling topics, allowing students to complete tasks through teamwork, thereby fostering collaborative spirit, practical ability, and innovative thinking.

By integrating multiple assessment methods, students are able to experience during the evaluation process that their creative thinking, proactive learning attitudes, and practical abilities can genuinely contribute to solving real-world problems. This effectively stimulates their interest in active learning and ultimately promotes a true transformation of course instruction from a teacher-centered approach to a student-centered learning model.

6. Analysis of the Implementation Effects of Teaching Reform

Through two consecutive semesters of teaching reform practice in university mathematics courses, a follow-up analysis was conducted on the classes implementing the reform. The results indicate that students showed significant improvement in classroom participation, autonomous learning ability, and innovative awareness.

From the perspective of classroom performance, after adopting problem-oriented teaching and the flipped classroom model, the frequency of student classroom interaction increased significantly, rising from an average of 5–8 interactions per class before the reform to more than 15 interactions per class. Students' enthusiasm for classroom participation was notably enhanced.

In terms of learning outcomes, according to statistical data collected from the information-based teaching platform, the completion rate of pre-class preparation increased from approximately 60% before the reform to over 85%, while the on-time submission rate of after-class assignments rose to more than 90%. These results indicate a substantial improvement in students' awareness of autonomous learning.

Regarding ability development, during the practical course sessions, students demonstrated an improved ability to apply mathematical modeling methods to analyze discipline-related problems. Some students actively participated in mathematical modeling competitions and innovation training programs, and their innovative thinking ability as well as teamwork skills were effectively enhanced.

Teaching feedback further showed that more than 85% of students believed that the new teaching model helped them better understand abstract mathematical concepts, increased their interest in learning, and improved their ability to solve practical problems..

7. Conclusions

University mathematics is an essential foundational course during undergraduate education and plays a significant supporting role in the cultivation of innovative talents. Through reforms in teaching methods, teaching content, and evaluation approaches, teachers have gradually transformed from knowledge transmitters into learning facilitators, while students have shifted from passive learners to active participants, becoming the central role of classroom learning. The student-centered teaching philosophy has been integrated throughout the entire teaching process of mathematics courses, effectively improving students' learning outcomes and innovative thinking ability.

In university mathematics teaching, greater attention should be paid to the practical application of mathematical modeling. Students should be guided to transform real-world problems into mathematical problems, thereby stimulating their awareness of objective methods in social life and enabling them to internalize knowledge into the ability to analyze and solve problems. This approach not only enhances students' mathematical competence, but also promotes the development

of innovative thinking and supports their all-round growth in the process of solving practical problems. Teaching practice has shown that these reform measures not only stimulate students' interest in exploration and innovative thinking, but also effectively improve their innovative ability and comprehensive competence in solving practical problems, while addressing key challenges in teaching practice. At the same time, it should be recognized that with the rapid development of society and technology, the exploration of cultivating students' innovative thinking ability is a gradual and long-term process that requires continuous improvement and sustained effort.

Therefore, constructing an integrated university mathematics teaching system that combines knowledge transmission, ability cultivation, and innovation development is an important direction for mathematics curriculum reform in higher education in the new era, and it also provides a practical reference for the cultivation of innovative talents under the background of emerging engineering education.

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