Research on the Practice of Higher Vocational Mathematics Teaching Based on a Mathematical Experiment Platform

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Abstract: For most vocational colleges, the introduction of mathematics laboratory courses is still in the continuous exploration phase, and the views on mathematics laboratory courses vary from one institution to another. In the two years since the introduction of mathematics experiments, we have adopted a combination of basic mathematical experiments and modeling mathematical experiments to open up students' horizons, stimulate their enthusiasm for learning mathematics, cultivate their awareness and ability to use mathematical methods with the aid of computers to solve practical problems, and foster their innovative spirit.

Keywords: Mathematical Experiments, Mathematical Software, Mathematica Software, Vocational College Mathematics, Mathematical Modeling

1. Introduction

Vocational college mathematics education emphasizes the basic principle of "necessary and sufficient." Its main purpose is not to learn the rigorous and abstract theoretical system of mathematics, but to enable students to possess certain basic mathematical knowledge. Combined with their major and future career needs, students learn the ideas and methods of mathematics, enabling them to have basic mathematical literacy and mathematical application skills.

Internationally renowned authority on mathematics education and Dutch mathematician Hans Freudenthal pointed out: "Mathematics education itself is a process. It is not only about imparting knowledge, but more importantly, allowing students to practice personally during the teaching process... Mathematics education must have its own laboratory, traditional teaching methods cannot achieve true mathematics education...". The introduction of mathematics laboratory courses in vocational colleges is to enable students to learn vocational mathematics better and more effectively, allowing students to acquire the mathematical basic knowledge needed for their major through application and exploration. Mathematics experiments rely on mathematical principles, and mathematics experimental teaching is based on classroom teaching models. In mathematics laboratory courses, with the help of computers' powerful calculation and plotting functions, students can not only fully apply the mathematical knowledge they have learned but also deepen their understanding of mathematical knowledge in practical operations.

2. Practice and Research on the Establishment of Mathematics Laboratory Courses

2.1. Using Mathematical Software as a Tool

Mathematical experiments are centered around mathematical software, and among a series of high-performance mathematical software, we have chosen Mathematica. Mathematica is an interactive, integrated computer software. It is capable of performing a variety of numerical and symbolic calculations for elementary mathematics, advanced mathematics, engineering mathematics, etc. It also has very powerful plotting capabilities; the nearly hundred plotting functions it contains are the best tools for data visualization, allowing for the convenient drawing of various curves, surfaces, and even the design of animations. Its syntax rules and representation methods are closer to the thinking and expression of mathematical operations. Programming with Mathematica allows for the completion of complex calculations and formula

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derivations with fewer statements. In addition, depending on the content of the experiment, more "professional" software for problem-solving can be appropriately added, such as SPSS for statistical processing and LINGO for planning problems. This broadens students' understanding and application of mathematical software. Let mathematical software become a good teacher and friend for students to learn mathematical knowledge and its applications.

2.2. Construction of Teaching Model

In 1998, the catalog and introduction of undergraduate majors in general colleges and universities clearly included mathematics experiments as a major course in mathematics-related majors. Today, the establishment of mathematics experiment courses in domestic universities is a main research outcome of the "Higher Education Facing 21st Century Educational Content and Curriculum System Reform Plan" by the Ministry of Education. There is an exploration of how to use mathematical software for case teaching and mathematical modeling. Therefore, in combination with the actual situation of the student population in vocational colleges, the mathematics experiment course adopts a teaching model that combines basic mathematical experiments with modeling mathematical experiments.

2.2.1. Basic Mathematical Experiments

Given the compression of class hours for public foundation courses in vocational colleges, it is challenging to establish a separate compulsory mathematics laboratory course. Therefore, it is possible to consider "synchronizing with classroom teaching," treating mathematical experiments as a "patch" in the teaching process, and transforming mathematical knowledge into a "technology" that can be operated hands-on through computers and mathematical software. It is recommended that the teaching hours be set between 10 and 16 class hours. In teaching, classroom instruction is still maintained, but complex calculations and derivations are appropriately reduced, focusing on teaching students mathematical concepts, mathematical ideas, and mathematical methods. According to the actual situation of each institution, an application can be made to the academic affairs management department to arrange the hours for mathematical experiments not to occupy classroom teaching hours, but to be conducted outside of class time.

Basic experiments are also an important model for our current mathematics laboratory courses. Practical teaching in mathematics laboratory courses can be carried out in two aspects:

Based on the introduction of the basic operations and commonly used commands of Mathematica, simulated mathematical experiments are conducted using the software's rapid calculation capabilities, graphic processing abilities, etc. It is recommended that this part be carried out in synchronization with classroom teaching, that is, the teacher demonstrates operations with mathematical software in the classroom.

By presenting different variations of the research object, problem situations are created to guide students to use different ways of thinking to explore mathematical knowledge and verify mathematical conclusions in exploratory mathematics experiments. Combining calculus (differential calculus, integral calculus, differential equations), engineering mathematics (linear algebra, series and Laplace transform, probability and statistics) to varying degrees in concept classes, problem classes, and application classes with mathematical experiments helps students understand concepts, escape from tedious calculations, and apply theory to practice.

One of the difficulties in mathematics teaching is the teaching of concept courses. Students often have a superficial understanding of mathematical concepts, failing to comprehend the fundamental issues reflected behind the concepts. A lack of understanding of concepts makes it difficult to proceed with further learning.

Below is a case example to introduce how to resolve the teaching difficulties of concept courses by integrating mathematical experiments.

[Typical Case 1]: Teaching design of "the concept of Fourier series" combined with mathematical experiments.

The Fourier series is a required knowledge point for students majoring in electronics and automation, but because its concept is too abstract and the formula is complex, and the mathematical foundation of vocational students is relatively weak, various objective reasons cause students to often be confused about

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what they are doing when learning about Fourier series. Therefore, to help students better understand the essence of the concept, the following teaching design is carried out when introducing the concept:

Pre-class task: Starting from the professional background, students are required to use an oscilloscope to adjust the waveform of a "square wave" during their specialized course training, and observe it carefully (as shown in Figure 1). Then the question is raised: "How is the 'square wave' formed? What is its relationship with the 'sine wave' we know?"

Classroom discussion: Through this link, what the teacher needs to do is to make the abstract and tedious theory intuitive and simple, making it easy for students to accept. The main use of Mathematica software's plotting function in this link is for the teacher to arrange the demonstration content purposefully. Let students plot the graphs of the following functions respectively, and through comparison and observation, discuss in student groups to reach a discussion result. In this process, the teacher guides students to discover the "law" that exists - multiple sine curves are continuously "superimposed".

Call the plotting command in Mathematica software: Plot [function, {var, min, max}], and use the command to present the graphs of two functions in the same plane Cartesian coordinate system.

Exploration and Communication: Posing conjectures and identifying patterns are crucial steps in the process of mathematical experiments. Analyzing the phenomena observed during experiments to find patterns and reaching conclusions through logical reasoning and conjecture are reflections of achieving the teaching goals of mathematical experiments. They are also vital for students' independent exploration and for stimulating their interest in learning. Through this process, students can comprehend that the formation of a square wave is indeed the result of the superposition of multiple specific sine waves. Teachers can also use examples such as "sawtooth waves" and "ramp waves" to repeat this process. Following this, the teacher can explain the concepts and formulas. Once students truly grasp the "essence" of a mathematical concept, learning it becomes much more manageable. The software can also be used to expand and compute the concepts of Fourier series, allowing students to focus more on understanding the concepts and applying knowledge.

The Mathematica software also has capabilities for graphic animation and sound playback, enabling students to attempt to create their own "mathematical animations." Consequently, on the foundation of the "prescribed" educational content, teachers can also incorporate these engaging features into the teaching of mathematical laboratory courses in a flexible manner, which can enhance students' enthusiasm for learning mathematical concepts and exploring the functionalities of the software.

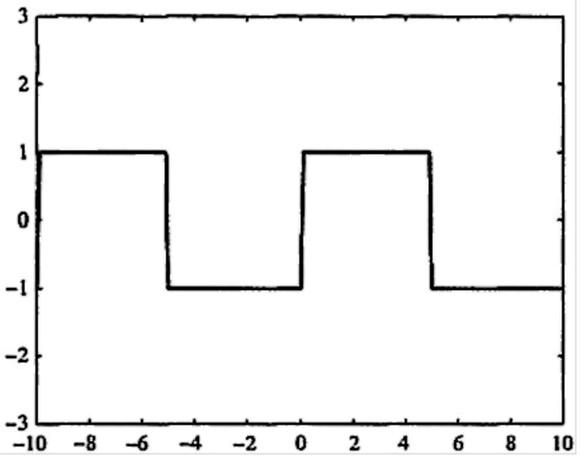

Figure 1:"Square Wave" Waveform

[Typical Case 2]: Function Animation Demonstration

Manipulate is a feature in Mathematica that allows users to interactively run functions and commands, making mathematical operations such as function expansion and integration "come to life," especially in animating the demonstration of function graphs, which is vivid and easy to grasp.

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By dragging the slider for the parameter a and adjusting its value, observe how the graph of the function $\sin(ax)$ changes with the value of the parameter a as shown in Figures 2 and 3.

Input: Manipulate [Plot [Sin[a*x], {x,0,9}, Plot Range→ {-2,2}], {a,0,2}]

Building on this foundation, the challenge can be further increased to model the motion of the Earth, Moon, and Sun. Provide fundamental data such as the radii of the Sun, Earth, and Moon, the Earth's orbital radius around the Sun, its orbital period, the Moon's orbital radius around the Earth, its orbital period, and the inclination of the Earth's orbit. Set this as an extracurricular assignment for students. Based on the students' performance, a certain score can be awarded and factored into their overall mathematics grade. This encourages students to continually explore the various features of the software and to use it as a tool for learning mathematical concepts and solving real-world problems.

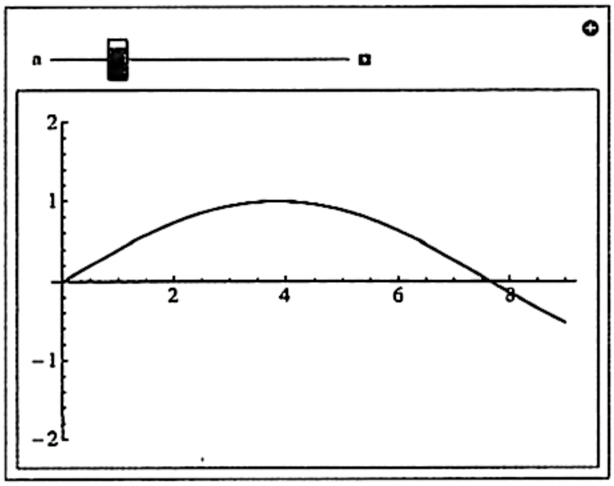

Figure 2: Function Demonstration

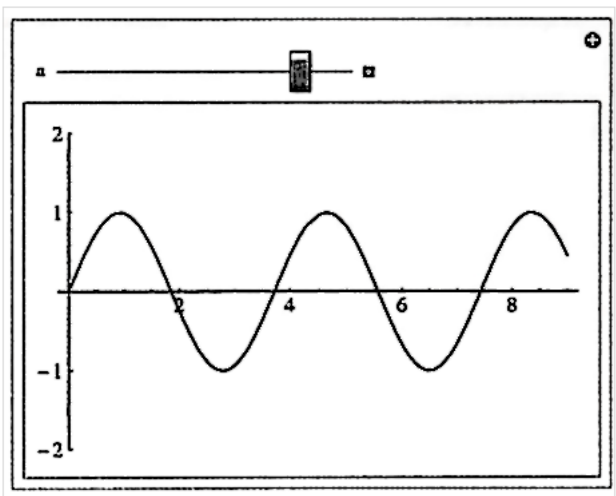

Figure 3: Function Demonstration

2.2.2. Modeling Mathematical Experiments

As the National College Students' Mathematical Modeling Competition gains momentum and the big data era arrives, the role of mathematical software in these competitions is becoming more and more significant. So much so, that a dedicated Mathematical Software Innovation Award has been set up for the national contest. Numerous institutions have introduced mathematical modeling courses in response to the thriving National College Students' Mathematical Modeling Competition, representing a valuable effort to cultivate students' capabilities in applying mathematics, which has been met with enthusiasm from students and received strong endorsement from the education sector. The establishment of mathematical experiment

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courses, based on the experience of mathematical modeling teaching and competition activities, represents another reform in mathematics education aimed at further enhancing students' abilities to utilize mathematics effectively.

Modeling mathematical experiments are conducted through elective courses on mathematical modeling and mathematical modeling clubs. The teaching hours can be flexibly arranged according to the specific situation without a fixed allocation. The goal is for students to build mathematical models during the experiments, which involves transforming real-world issues from life and production, after suitable conditional constraints and abstraction, into mathematical problems, and then selecting the right mathematical methods to solve them. These methods can be either elementary or advanced. Such experiments typically consist of five main phases: gathering and organizing materials, formulating model assumptions, establishing mathematical models, analyzing and solving the models, and researching model reduction. These experiments are highly integrative in nature. On top of grasping the basics of experimental content, students further explore how to apply software to address real-world problems. It also prepares them well for participating in the National College Students' Mathematical Modeling Competition. Teachers can break down mathematical modeling problems into specialized, realistic issues for students, such as fitting experiments (learning to use Mathematica software for data fitting and multivariate data interpolation), optimization experiments, etc., all of which are excellent projects for experimentation. Gradually increasing the complexity of the problems, and ultimately focusing on the problems from the National College Students' Mathematical Modeling Competition, will continuously hone students' abilities in mathematical modeling.

3. The Outcomes of Introducing Mathematical Experiments

The introduction of mathematical experiment courses and mathematical software has expanded students' horizons. Many students' perceptions of mathematics are still rooted in the high school phase, characterized by "endless exercises," "formulas," and "theorems," with virtually no knowledge of mathematical software. In reality, the evolution of computer technology has given rise to numerous outstanding mathematical software applications. Mathematical experiment courses have significantly ignited students' interest in learning; they find operating the software to be a novel and enjoyable experience. By utilizing the software to call up functions and input programs, desired results can be achieved with a single click, which students perceive as "amazingly magical." Math classes have transformed from being just a teacher's "incessant lecture" at the front and students' "silent absorption" in the audience. By leveraging computer technology effectively, students can embrace the subject with their preferred "playful" mindset and appreciate how computer-assisted solutions can tackle the advanced mathematics challenges that once caused them "fear."

The integration of mathematical experiment courses shifts the conventional teaching paradigm from "lecture—imitation—memorization" to" observation—thinking—conjecture—verification," altering students' perception of what constitutes an "experiment." This approach enables students to gain a holistic understanding of the fundamental concepts and theories within mathematics. By animating static mathematical concepts and leveraging the software's capabilities to vividly present them, students are better equipped to comprehend the nature of these concepts.

When we grasp the full story behind any subject, its mystery and inscrutability fade away. This is true for mathematical concepts, theorems, and formulas as well. The "origins" refer to their background and developmental process (including derivations and proofs in mathematics), while the "trajectory" represents the practical applications of mathematical knowledge. Basic mathematical experiments tackle the "origins," and modeling mathematical experiments address the "trajectory."

4. Key Considerations for Offering Mathematical Experiment Courses

4.1. Basic Experiments

During the instruction of basic experiments, it is essential to adhere to the principle of "students as the primary participants and teachers as facilitators." This approach allows students to engage directly in the

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entire problem-solving process, with teachers providing guidance when students encounter difficulties, without being overly intrusive in the students' experimental activities.

Additionally, it is crucial to maintain the principle that "mathematical experiments are in service of mathematical knowledge and principles." The integration of mathematical experiments should foster innovation in teaching content and methods. The use of mathematical software should be approached with a balanced perspective to prevent students from becoming overly reliant on it, potentially neglecting the study of mathematical thought and methodology. It is important to avoid the misconception that learning is solely about acquiring software operation skills.

Develop a Scientific and Rational Approach to Assessing Mathematical Experiments. Mathematical experiments differ from manual calculations; they are completely open and do not have fixed parameters. The conditions for an experiment can be assumed, and there may be multiple outcomes, which means that the assessment of mathematical experiments should consider various aspects and be more flexible in grading. It is suggested that the evaluation of mathematical experiments mainly be conducted through computer-based assessments, preferably under the supervision of a teacher, to be completed by students either individually or in groups, based on the assessment criteria. Additionally, students should be required to write an experimental report based on the content of the experiment. The report serves as a written summary and reflection of the experiment's outcomes, including the objectives, content, process, and analysis of the results, as well as the insights gained from the experiment, such as understanding and mastering mathematical knowledge and its applications. Furthermore, the assessment scores for mathematical experiments must be incorporated into the overall mathematical grade, with the percentage of the grade determined based on actual circumstances, and it is recommended that this should not be less than 20%.

4.2. Modeling Experiments

During modeling experiments, it is crucial to maintain a student-centered approach and progressively engage in investigative and exploratory learning. Given that the academic foundation of vocational students is inherently weaker, particular care should be taken in selecting the content of experiments. Start with the most straightforward experiments to foster their interest and passion for learning. Then, gradually increase the complexity, evolving from simple mathematical problems to more complex, real-world applications, thereby enhancing students' practical abilities step by step. The establishment of modeling experiment courses is akin to unlocking a gateway for students to apply mathematics, revealing that mathematical knowledge extends far beyond the traditional understanding of intricate theory proofs and formulaic computations. It is, in fact, extensively utilized in every facet of our daily lives.

4.3. Development of Mathematical Experiment Teaching Resources

Strengthen the construction of various resources for mathematical experiment courses. The success of implementing mathematical experiments is intricately linked to the quality of the teaching faculty. The introduction of such courses sets higher standards for teachers, particularly for the older educators who may not be well-versed in computer operations, thus making this educational innovation a significant challenge for them. It is crucial to capitalize on the pioneering role of young teachers, who should be willing to take on substantial responsibilities and form collaborative "mentor-mentee" relationships with senior teachers for mutual assistance.

Furthermore, the development of course-related resources, including teaching materials, case studies, textbooks, and electronic courseware, necessitates ongoing research and practical application. The current textbooks available for mathematical experiments are primarily intended for undergraduate and higher-level students. Each educational institution should consider its unique circumstances and craft its own school-specific textbooks that are appropriate for its needs. Moreover, for institutions with sufficient funding, it is recommended to establish specialized mathematical laboratories. This would provide an enhanced environment for teachers to explore and investigate mathematical software and experiment cases.

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5. Conclusion

Today, mathematics, a discipline of natural science, has transcended the boundaries of knowledge to become a "technology" that can be realized through computers. Over the two years since the introduction of mathematical experiment courses, we have keenly sensed the students' passion and interest in them, despite their imperfections. These courses enable us to refresh teaching content and methodologies, thereby facilitating educational reforms and modernizing teaching methods. The advent and evolution of computer technology, particularly the emergence of various mathematical software, have progressively altered traditional perceptions of mathematics, broadened our understanding of it, and transformed our initial comprehension of conventional experiments. The goal of mathematical experiments is to ignite students' enthusiasm for learning mathematics, heighten their consciousness of applying mathematical concepts, and foster their capability to apply mathematical knowledge and computer technology to recognize and resolve real-world issues. Although mathematical experiments do not supplant proof, they have become an increasingly vital component of mathematics, exerting a significant influence on the teaching of mathematics in higher education and profoundly affecting the educational system's structure, as well as both teachers and students.

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