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Teaching Reform Practice of Advanced Mathematics under the "Theory-Practice Integration" Concept — Taking the Derivative Teaching in Mechanical Major as an Example

Jiaojiao Feng
Wenzhou Vocational and Technical College, Wenzhou, China
Email: 292012900@qq.com

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Abstract

In response to the prevalent issues in advanced mathematics teaching, such as the overemphasis on theory at the expense of application and the disconnection from professional demands, this paper, grounded in the educational philosophy of "integration of theory and practice," puts forward a systematic approach to teaching reform. The reform proposes a shift in teaching logic from the traditional knowledge-system orientation to a real-work-scenario orientation, reconstruct-ing the curriculum content system with typical engineering tasks as the carrier. Taking "the application of derivatives in cam mechanisms" for mechanical engi-neering majors as a case study, a three-stage progressive teaching process—"engineering task introduction → mathematical principle exploration → engi-neering problem solving"—is constructed. Teaching practice demonstrates that this reform has significantly enhanced stu-dents' intrinsic learning motivation and their ability to apply mathematical knowledge to engineering practice.

Keywords

Advanced Mathematics; Integration of Theory and Practice; Teaching Reform; Engineering Cases; Applications of Derivatives

1. Introduction

Advanced Mathematics is a fundamental course for engineering disciplines, yet it still faces two prominent challenges[1] in actual teaching: first, the curriculum overemphasizes theoretical derivations, leading students to commonly perceive the course as "abstract, difficult to understand, and seemingly useless"; second, there is poor integration between this course and subsequent specialized courses, making it difficult for students to effectively transfer and apply their mathematical knowledge

to real engineering problems.

The educational philosophy of "integration of theory and practice" emphasizes the organic unity of theoretical instruction and practical training, advocating the use of typical work tasks as vehicles to achieve deep integration of "learning by doing and doing while learning." Taking the teaching module on "Applications of Derivatives" in mechanical engineering as an example[2-3], this paper explores a path toward the "engineering-oriented" reform of Advanced Mathematics. By leveraging the cam mechanism—a typical engineering case—the core concepts such as function monotonicity, concavity/convexity, and inflection points are systematically integrated into a complete, coherent analytical task with clear engineering relevance.

2. Reform approach: From "knowledge logic" to "work logic"

The traditional teaching of advanced mathematics generally follows the knowledge logic path of "definition → theorem → proof → example → practice". Although this model helps to ensure the systematicness, rigor, and internal coherence of the mathematical knowledge system, it often leads students to feel alienated from the purpose of learning mathematics and makes it difficult for them to form a practical cognition and value recognition of "what is the use of mathematics". The core concept of this round of teaching reform lies in: based on the inherent working logic of engineering tasks, systematically reconstruct the teaching process and organizational model of advanced mathematics.

The essential differences between the two logic paths are reflected in three dimensions: the knowledge logic starts from the strict definition of mathematical concepts, organizes teaching based on the abstraction, hierarchy, and logical progression of knowledge, and the mathematical knowledge itself is the ultimate object of learning; while the work logic starts from real or typical engineering problems, conducts teaching around the actual progressions such as task analysis, modeling, solving, and verification, and the mathematical knowledge is positioned as the key tool and analytical means to support problem-solving in this process. The former easily leads students to fall into the cognitive confusion of "why learn", while the latter helps students truly understand the practical significance and methodological value of "how can mathematics solve such problems" in the process of problem-solving.

Based on the above concepts, this reform focuses on promoting three key turns: first, at the content organization level, break the traditional linear arrangement based on textbook chapters, and integrate and reconfigure knowledge across chapters according to the demand sequence of typical engineering tasks; second, at the teaching implementation level, shift from one-way knowledge teaching to driven teaching with real tasks as the carrier, emphasizing the construction of knowledge meaning and ability transfer in the process of task completion; third, at the value

orientation level, go beyond the ontological value of mathematics as a formal science, and highlight its application value and educational function as an engineering analysis, modeling, and decision support tool.

3. Reform Practice: Taking the Teaching of Derivatives of Cam Mechanisms as an Example

3.1. Selection and Design of Engineering Tasks

The engine valve cam mechanism was chosen as the teaching carrier for three reasons: the cam is a typical part in the mechanical field, and students have a sense of professional identity; the analysis of the cam profile directly involves the concept of derivatives (displacement → velocity → acceleration); the task is progressive, and it can connect multiple knowledge points such as monotonicity, concavity, and inflection points.

The core engineering task of the design is: to analyze the motion law of the cam follower and answer three questions - when does the follower rise and when does it fall? When does it accelerate and when does it decelerate? Where is the maximum speed located? These three questions correspond to the monotonicity, concavity, and inflection points of the function respectively.

3.2. Reorganization of teaching content

Based on the above engineering tasks, the content of the "Application of Derivatives" chapter will be reorganized into three progressive modules.

Module One addresses the "Forward/Backward" problem, with the mathematical tool being the first derivative symbol, and the core concept being the monotonicity of the function. Module Two addresses the "Acceleration/Deceleration" problem, with the mathematical tool being the second derivative symbol, and the core concept being the concavity and convexity of the function. Module Three addresses the "Maximum Speed Point" problem, with the mathematical tool being when the second derivative is zero and changes sign, and the core concept being the inflection point.

The three modules follow the same loop: engineering question → mathematical tool → conclusion verification → engineering meaning.

3.3. Teaching Implementation Process

This section of the teaching adopts a closed-loop process. Before class, students watch a video about the operation of the cam and complete a test on the basic knowledge of derivatives to establish a background understanding.

During the class, it focuses on three progressive engineering problems. First, the core task is presented, allowing students to enter the learning process with questions. Then, through interactive pages, the synchronous relationship between

the cam rotation and the displacement curve is demonstrated to establish an intuitive correspondence. On this basis, three engineering problems are solved successively: using the sign of the first derivative to determine the forward stroke and the reverse stroke, using the sign of the second derivative to determine acceleration and deceleration, and using the turning points to locate the maximum speed. Each problem follows the path of "engineering question → mathematical tool → conclusion verification". Finally, a classroom quiz is conducted to test the learning effect and to clarify the correspondence between the mathematical conclusions and the engineering meanings.

3.4. The design of key teaching segments

One of the key designs of this section of teaching is "first intuitive perception, then abstract definition". Taking the correspondence between concavity and acceleration as an example, in traditional teaching[4-7], the definition is directly given and students can only memorize it mechanically. The reformulated approach is: first, through the interactive page, as shown in Figure 1, observe the correspondence between the shape of the curve and the change in speed, then introduce the second derivative as a descriptive tool, and finally, verify through differentiation calculation. This approach conforms to the cognitive law from the concrete to the abstract.

Another design is to link multiple knowledge points through a series of questions: three engineering problems correspond to monotonicity, concavity, and inflection points respectively. Students naturally complete the knowledge integration when solving the same engineering task.

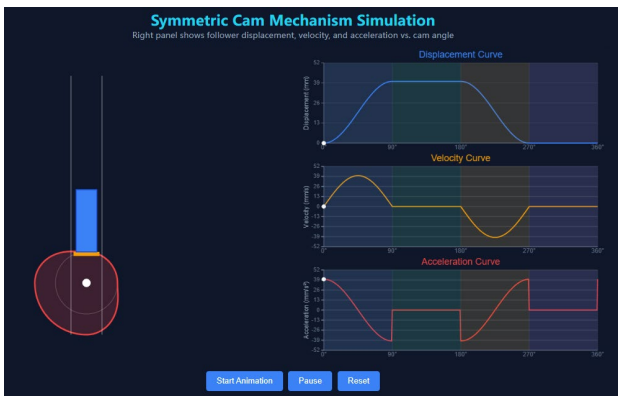


Figure 1. Crankshaft rotating interactive page

4. Reform effects and evaluations

By comparing with previous cohorts of students, the main achievements can be summarized in three aspects.

In terms of learning interest, the participation rate in classroom interaction has significantly increased, and the frequency of students' active questioning has also risen. The types of questions have shifted from "How to solve this problem?" to

"Where can this be applied in the field of the major? ".

In terms of concept understanding, in the examination of the relationship between concavity and acceleration, the accuracy rate has significantly improved. Students no longer merely memorize mechanically, but can make judgments based on the shape of the curve.

In terms of engineering awareness, students can actively correlate mathematical conclusions with engineering meanings. For example, when analyzing inflection points, they can say "When the speed is at its maximum, consideration should be given to the impact", rather than just completing the mathematical calculations.

Areas for improvement: Some students still have difficulties in calculating second derivatives. Further targeted training is needed in the future; a few students overly rely on visualization tools, and the combination of tool usage and independent derivation needs to be strengthened.

5. Conclusion

This article takes the application of derivatives in cam mechanisms as an example to explore the path of "engineering-oriented" teaching reform in advanced mathematics. Practice has shown that using real engineering tasks as the carrier and reconfiguring the teaching process based on work logic can effectively solve the problem of "learning but with no practical value", and achieve the unity of knowledge learning and ability cultivation.

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