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Research on the Pedagogical Pathways for Integrating Mechanisms with National Strategic Demands

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Abstract: This study focuses on the integration of mechanism course with national strategic needs, aiming to explore a new teaching model to cultivate high-quality engineering and technical talents that meet the demands of intelligent and green manufacturing. The research begins by analyzing the demand for mechanical engineering talents against the backdrop of the current national strategy, and then proposes strategies for reforming the content and teaching methods of mechanism course. By adding content related to intelligent and green manufacturing, adopting case-based and project-based teaching methods, implementing a hybrid online-offline teaching model, strengthening the cultivation of practical abilities and school-enterprise cooperation, and integrating the education of socialist core values, this study has constructed a mechanism course system that meets the requirements of the new era. The implementation of the study is expected to significantly improve the teaching quality of mechanism course and cultivate more mechanical engineering talents with strategic thinking and practical capabilities.

1. Introduction

As the global economy becomes increasingly integrated and technological revolutions continue to unfold, China is at a critical juncture in its transition from a "manufacturing giant" to a "manufacturing powerhouse." This transformation necessitates not only technological innovation and industrial upgrading but also a significant influx of high-quality engineering and technical professionals equipped with innovative capabilities and practical skills. Mechanical engineering, as the cornerstone of the manufacturing sector, plays a pivotal role in the quality of talent cultivation, which is directly linked to the effectiveness of national strategic implementation. Mechanisms, as a foundational course within the domain of mechanical engineering, carries the essential task of nurturing students' innovative and engineering practical competencies [1, 2].

However, traditional mechanism course often emphasizes the dissemination of theoretical knowledge, lacking effective alignment with national strategic demands, which hinders the stimulation of students' enthusiasm for learning and their potential for innovation. Against the backdrop of the nation's vigorous promotion of significant strategic initiatives such as intelligent and green manufacturing, there is an urgent need for a reform in mechanism education to adapt to the developmental needs of the new era [3-5]. Therefore, exploring a novel pedagogical model that integrates mechanism course with national strategic demands is of paramount importance for enhancing students' sense of national mission and fostering their innovative spirit.

This study aims to explore the pedagogical pathways for integrating mechanism course with national strategic demands, through the renewal of course content, the reform of teaching methodologies, the cultivation of practical competencies, and the infusion of ideological and political education into the course. The research content and expected outcomes are shown in Figure 1. The goal is to establish a course system that aligns with the demands of the new era. The anticipated outcome of this project is a significant enhancement in the quality of mechanism education, with the aim of cultivating a more substantial cohort of mechanical engineering professionals who are endowed with strategic thinking and practical capabilities for the nation.

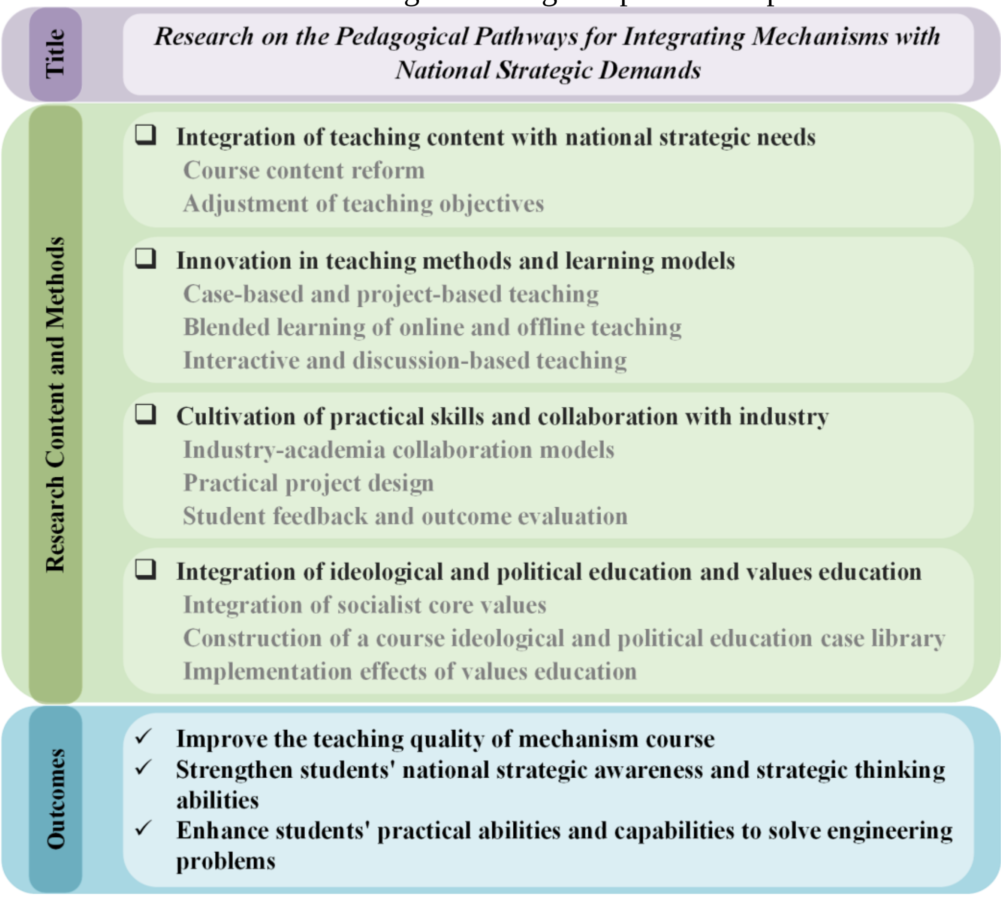

Figure 1: Research content and expected outcomes of this study.

2. Integration of Teaching Content with National Strategic Needs

2.1. Course Content Reform

The course content of mechanisms is shown in Table 1. To integrate the content of the mechanism course with national strategic needs, course reform should include the following aspects:

(1) **Incorporate content on intelligent manufacturing:** Introduce basic concepts, key technologies, and application cases of intelligent manufacturing, such as Industry 4.0, the Internet of Things, and big data analysis. Through the study of these contents, students can understand the latest development trends and application prospects of intelligent manufacturing.

(2) **Integrate the concept of green manufacturing:** Allow students to understand how to consider energy saving, emission reduction and material recycling in mechanism design through case analysis. For example, the application of green manufacturing in automobile, electronics, chemical and other industries can be analyzed, and how to realize the greening of production process through mechanism design can be discussed.

(3) **Tracking the latest technological trends:** Update the course content in a timely manner, reflect the latest research findings and technological developments in the field of mechanisms, such as parallel robots, metamorphic mechanisms, micro/nano mechanisms, etc. These contents can help students understand the cutting-edge dynamics in the field of mechanisms and stimulate their innovative thinking.

(4) **Case analysis:** Select practical industrial cases related to intelligent and green manufacturing, allow students to deeply understand the application of mechanisms in modern manufacturing through analysis and discussion. Case analysis can include design cases, production cases, management cases, etc., and through case teaching, improve students' practical abilities and problem-solving skills.

Table 1: The main content of the mechanism course

Chapter 1	Introduction	1. Current state of the development of mechanisms
Chapter 2	Mathematical foundations of advanced mechanism	1. Common coordinate transformations and matrices 2. Solutions to systems of nonlinear equations 3. Numerical solutions to systems of ordinary differential equations
Chapter 3	Structural theory of mechanisms	1. Theory of mechanism composition 2. Degrees of freedom of spatial mechanisms 3. Structural synthesis and type synthesis of kinematic chains
Chapter 4	Kinematic analysis of mechanisms	1. Kinematic analysis of planar and spatial mechanisms
Chapter 5	Kinematic synthesis of lower-pair mechanisms	1. Synthesis of rigid-body guidance mechanisms 2. Synthesis of path-generating mechanisms 3. Synthesis of function-generating mechanisms
Chapter 6	Theoretical foundations of higher-pair mechanisms	1. Instantaneous center-line mechanisms and their design 2. Conjugate curve mechanisms and their design
Chapter 7	Introduction to robotic mechanisms	1. Types of robotic mechanisms 2. Pose analysis of robotic mechanisms 3. Kinematic analysis of robotic mechanisms 4. Dynamic analysis of robotic mechanisms
Chapter 8	Bionic mechanisms	1. Fundamentals of biomechanics 2. Types of bionic mechanisms
Chapter 9	Balance of planar mechanisms	1. Principles of balance for planar mechanisms 2. Balance of inertial forces in planar mechanisms 3. Balance of inertial torques in planar mechanisms
Chapter 10	Elastic dynamics of mechanisms	1. Elastic dynamics of cam mechanisms 2. Elastic dynamics of linkage mechanisms
Chapter 11	Dynamics of mechanical systems	1. Dynamics of single-degree-of-freedom mechanical systems 2. Dynamics of multi-degree-of-freedom mechanical systems

2.2. Adjustment of Teaching Objectives

In accordance with national strategic needs, the teaching objectives of the mechanism course should be adjusted to:

(1) **Cultivate innovative design ability:** Enable students to use mechanism knowledge to carry out innovative mechanical design. This includes designing new types of mechanism systems to adapt to the needs of intelligent and green production.

(2) **Enhance practical skills:** Improve students' ability to solve practical engineering problems through school-enterprise cooperation and laboratory practice. The cultivation of practical skills is an important goal of mechanism teaching, and through practical teaching, students can apply theoretical knowledge to the solution of practical problems.

(3) **Strengthen environmental awareness:** Cultivate students' environmental awareness and social responsibility in the design and manufacturing process. This includes understanding environmental protection regulations, learning about environmentally friendly materials and processes, and mastering energy-saving and emission reduction technologies.

(4) **Broaden international perspective:** Encourage students to pay attention to the development trends of the international manufacturing industry and understand the importance and application prospects of mechanisms. Cultivating an international perspective can help students better understand the development dynamics of the global manufacturing industry and lay the foundation for their future international cooperation and competition.

3. Innovation in Teaching Methods and Learning Models

3.1. Case-based and Project-based Teaching

(1) **Case-based teaching:** In mechanism course, analyzing real mechanical system cases allows students to understand the practical applications and challenges faced in mechanism design. Cases can include historical mechanical inventions, modern mechanical system design and optimization, and the application of mechanical systems in various engineering fields. Through case analysis, students can integrate theoretical knowledge with real-world problems, improving their ability to solve complex engineering issues.

- Historical cases: Study the ancient Chinese machinery such as water rafts, compass cars, etc., and analyze the principles of their mechanism design.
- Modern cases: Discuss the mechanism design of automotive power transmission systems, and analyze how to realize efficient energy conversion and transmission.
- Cross-disciplinary applications: Investigate the mechanism design in medical equipment, aerospace and other fields to understand their contributions to improving the quality of life and technological innovation.

(2) **Project-based teaching:** This approach focuses more on student participation and hands-on practice. In mechanism course, a series of projects related to the course content can be designed, such as designing a simple robotic arm, optimizing a mechanical transmission system, or developing simulation software for mechanism motion. Students need to apply principles and methods of mechanisms in their projects for design, analysis, and testing, thereby gaining a deep understanding of mechanism knowledge.

- Robotic arm design: Design a robotic arm capable of performing specific tasks (such as lifting or painting), and consider its range of motion, precision and stability.
- Transmission system optimization: Analyze the mechanism design of existing mechanical transmission systems (such as bicycles, automobiles), and propose improvement schemes to increase efficiency or reduce energy consumption.
- Simulation software development: Develop software capable of simulating mechanism motion, and analyze its performance, such as mechanism dynamics analysis tools based on MATLAB/Simulink.

3.2. Blended Learning of Online and Offline Teaching

(1) **Online teaching:** Online platforms can provide resources such as basic theoretical knowledge of mechanisms, animated demonstrations, and simulation software, allowing students to engage in self-directed learning outside the classroom. Online platforms can also simulate remote experimental operations, offering students with a virtual laboratory environment.

▪ Online course resources: Provide detailed course notes, interactive learning modules, self-assessment questions, so that students can master the learning progress independently.

▪ Virtual laboratory: Utilize virtual reality technology to build and test mechanisms in a virtual environment, so that students can experience different institutional designs and motion effects.

(2) **Offline teaching:** Focuses on face-to-face interactive discussions, experimental operations and practical applications. Teachers can organize group discussions, experimental design, model building, and other activities to promote communication and cooperation among students while deepening their understanding of mechanism knowledge.

▪ Laboratory operations: Build, test, and analyze mechanisms in the laboratory, so that students can operate and observe the actual motion of mechanisms.

▪ Field trips: Organize visits to factories, research and development centers, etc., so that students can gain a direct understanding of the application of mechanism design in actual production.

3.3. Interactive and Discussion-based Teaching

(1) **Interactive teaching:** Stimulating students' interest and participation through questioning, immediate feedback, group competitions, and other forms. In mechanism course, teachers can design interactive segments, such as having students design a mechanism model in groups, then present and evaluate them, to enhance students' sense of participation and achievement.

▪ Classroom interaction: Use the response systems (such as Kahoot) for real-time Q&A to encourage students to actively participate in classroom discussions.

▪ Group competitions: Design mechanism design competitions where students work in groups to design and present their mechanism models within a limited time.

(2) **Discussion-based teaching:** Focuses more on the exchange of ideas and knowledge collision among students. Teachers can pose open-ended questions or controversial topics to guide students in in-depth discussions. For example, discussing how traditional mechanism design can be innovated and improved in the context of intelligent manufacturing, or how mechanism design can achieve energy saving and emission reduction under the concept of green manufacturing.

▪ Thematic discussions: Organize in-depth discussions and research around themes, such as intelligent and green manufacturing.

▪ Case studies: Analyze specific mechanism design cases, allow students to discuss the reasons for their success or failure and lessons learned.

4. Cultivation of Practical Skills and Collaboration with Industry

4.1. Industry-Academia Collaboration Models

Industry-academia collaboration is an essential pathway in higher education for enhancing students' practical skills, especially in the field of mechanisms, where such partnerships can provide students with real-world engineering experiences, strengthening their professional skills and employability.

(1) **Internships and practical training:** Collaborate with enterprises to offer students internship opportunities, so that students can participate in actual projects, experience the entire process of

mechanism design, manufacture and debugging, so as to obtain valuable practical experience.

(2) **Joint projects:** Develop projects in collaboration with enterprises, so that students can participate in project planning, design, implementation and evaluation under the guidance of teachers and enterprise engineers, and learn how to apply theoretical knowledge to solve practical problems.

(3) **Integration of industry, academia and research:** Promote collaboration between schools, enterprises and research institutions to foster innovation in knowledge and technology, which can provide students with opportunities to engage in cutting-edge research.

4.2. Practical Project Design

Practical project design is a crucial component of mechanism education, helping students apply theoretical knowledge to solve real-world problems.

(1) **Project theme selection:** Select project themes related to intelligent manufacturing, green manufacturing, etc., and ensure alignment with national strategic needs. These project themes should have practical application value and be capable of addressing real issues faced by enterprises or society.

(2) **Clear project objectives:** Each practical project should have well-defined learning objectives, including knowledge application, skill development, and quality enhancement. Project objectives should be specific, measurable, and matched with students' learning progress and ability levels.

(3) **Project process management:** Design detailed project implementation plans, including scheduling, task assignment, resource allocation and quality control. Project process management should ensure smooth progress and timely adjustments to address potential issues.

(4) **Project outcome evaluation:** Establish a fair and reasonable project evaluation system to assess student participation, innovation and the practical effectiveness of the project. Project outcome evaluation should consider not only the final results but also students' performance and learning gains during the project process.

4.3. Student Feedback and Outcome Evaluation

Student feedback and outcome evaluation are essential for improving practical teaching.

(1) **Feedback collection:** Collect students' opinions and suggestions on practical projects through questionnaires, interviews, discussions, etc. This feedback can help teachers understand students' needs and expectations, as well as the strengths and weaknesses of practical projects.

(2) **Outcome presentation:** Organize practical project outcome presentations to let students showcase their work and receive evaluations. Outcome presentations can enhance students' sense of achievement and confidence and serve as a platform for learning and exchange.

(3) **Effectiveness evaluation:** Use a combination of quantitative and qualitative methods to assess the effectiveness of practical teaching. Effectiveness evaluation should comprehensively consider all aspects of the project, including student satisfaction, actual benefits, and potential social impact.

(4) **Teaching improvement:** Adjust and optimize practical project design, improve teaching methods and means according to student feedback and outcome evaluation results. Teachers should constantly improve their teaching to adapt to the development of education and industry.

5. Integration of Ideological and Political Education and Values Education

5.1. Integration of Socialist Core Values

Incorporating socialist core values into the mechanism course is an essential pathway to fulfill the fundamental task of moral education and talent cultivation. By integrating socialist core values with the content of mechanism course, students can be guided to develop a correct worldview, outlook on life, and values.

(1) **Course design:** Combine the development history of China's manufacturing industry when explaining the basic concepts and principles of mechanisms, so as to cultivate students' patriotic feelings and sense of social responsibility. Additionally, introduce China's achievements in mechanism design in fields such as high-speed rail and aerospace to show the rapid development and enhanced international status of China's manufacturing industry.

(2) **Case teaching:** Select mechanical engineering cases that reflect socialist core values, such as mechanism design of China's high-speed rail and large aircraft, so that students can feel the great achievements of national development while learning professional knowledge. Additionally, analyze the technical difficulties, innovation points and team spirit to guide students to understand the application of socialist core values in practical work.

(3) **Discussion and reflection:** Organize students to discuss the moral and responsibility issues in the design of institutions, and guide students to think deeply and practice the core values of socialism. Through group discussions, debates, and other forms, students can learn to look at problems from different angles and cultivate critical thinking in communication.

5.2. Integration of Socialist Core Values

Building a course ideological and political education case library is an effective way to enhance the quality of ideological and political education in mechanism course. The construction of the case library should be combined with the professional characteristics of mechanisms and select typical cases that reflect socialist core values.

(1) **Case library construction:** Collect and organize cases related to mechanisms that are relevant to ideological and political education, such as the professional spirit and sense of responsibility demonstrated by Chinese engineers in international engineering projects, and the innovative thinking and teamwork reflected in solving engineering problems. The construction of the case library should focus on the diversity and timeliness of the cases to ensure they reflect the latest trends in society and industry development.

(2) **Application of case teaching:** Regularly use case library for teaching in mechanism course, and allow students to learn and experience socialist core values through case analysis, role-playing and group discussions. Case teaching should focus on student participation and experience, encouraging students to actively explore and think.

(3) **Case updates and feedback:** Regularly update the content of the case library, absorb feedback from students and teachers, and continuously optimize the teaching effects of the cases. Case updates should be combined with the latest social development trends and educational needs to ensure the practicality and educational value of the cases.

5.3. Integration of Socialist Core Values

The implementation effects of values education are an important indicator to evaluate the success of teaching activities. In mechanism course, the implementation effects of values education can be assessed in various ways.

(1) **Teaching effectiveness evaluation:** Understand students' acceptance and feedback on the ideological and political content of the course through questionnaires, interviews, classroom observations, and other methods to evaluate teaching effectiveness. The evaluation results should be used as an important basis for teaching improvement, constantly adjusting teaching strategies and methods.

(2) **Student capability enhancement:** Focus on the enhancement of students' abilities in value judgment, moral reasoning and social responsibility awareness during the course of study, and consider these abilities as important indicators of teaching evaluation. Through course learning, students should be able to better understand and apply socialist core values, forming good professional ethics and behavioral habits.

6. Conclusions

This study has effectively aligned the mechanism course with national strategic demands by updating teaching content and methods, and enhancing practical ability cultivation. The integration of diverse teaching strategies and practical projects has improved student engagement and outcomes. Strengthened industry-academia collaboration has provided valuable hands-on experiences, enabling students to apply their knowledge to real-world challenges. Furthermore, the infusion of ideological and political education has fostered a sense of social responsibility and professional ethics among students.

Overall, the teaching reform strategies proposed are significant for enhancing the quality of mechanism courses and meeting national strategic needs. Future efforts will focus on optimizing these reforms to ensure ongoing alignment with the evolving national strategies.

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