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Research on the Teaching Reform of "Problem-Oriented" Teaching Mode in the Course Design of Basic Mechanical Design

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Abstract: *With the increasing demand for high-quality applied engineering and technical talents in society, the traditional teaching mode of mechanical design basic course design can no longer meet the requirements of modern education. Taking Liaoning University of Science and Technology as an example, this paper explores the necessity and feasibility of introducing the "problem-oriented" teaching mode in the design of mechanical design basic course, and puts forward specific teaching reform measures and practical methods, aiming to improve students' innovation and practical ability, and cultivate high-quality engineering and technical talents that meet the needs of social development.*

Keywords: *Mechanical Design, Course Design, Problem-Oriented, Teaching Mode, Teaching Reform*

1. Introduction

As a core practical course for mechanical majors, the course design of basic mechanical design is an important bridge between theoretical knowledge and engineering applications. This course aims to cultivate students to systematically master the basic principles, methods and skills of mechanical design, and train students' engineering thinking, innovation ability and teamwork spirit through comprehensive design projects. However, with the rapid transformation of modern manufacturing industry towards intelligence and digitalization, the traditional teaching model has gradually exposed prominent problems[1].

Taking the construction of "new engineering" as an opportunity, the School of Mechanical Engineering of Liaoning University of Science and Technology proposed to introduce the "problem-based learning" teaching model (PBL) into the design of basic mechanical design courses. This model simulates real engineering problems and guides students to independently build a knowledge system in the cycle of "proposing problems-analyzing problems-solving problems". It not only conforms to the reform direction of "student-centered and results-oriented" in the "Certification Standards for Engineering Education Majors in Higher Education Institutions" of the Ministry of Education, but also provides a practical path for cultivating innovative engineering and technical talents that meet the needs of the intelligent manufacturing era[2].

2. Theoretical Basis of Problem-Oriented Teaching Model

Problem-based learning (PBL) is a student-centered, problem-based teaching method that emphasizes the process of raising, analyzing and solving problems to cultivate students' autonomous learning ability, innovation ability and teamwork spirit[3]. The logical structure is shown in Figure 1. The following is the theoretical basis of this model and its specific application in the design of the basic mechanical design course:

2.1 Focus on problems to stimulate students' learning interest and initiative

The PBL model emphasizes guiding students to learn through real problem situations. For example, in the basic mechanical design course, teachers can raise a practical engineering problem, such as "how to design an efficient mechanical transmission system", so that students can master relevant knowledge in the process of solving the problem[4-5]. This problem-driven learning method can stimulate students'

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curiosity and learning motivation, and enable them to actively participate in learning.

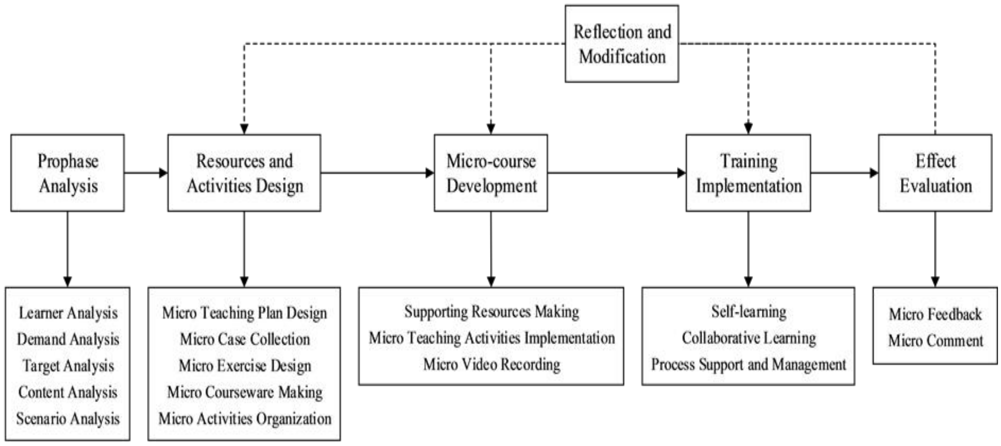

Figure 1 Structure of problem-oriented teaching model

2.2 Emphasize the students' dominant position and promote their independent learning and exploration

In the PBL model, students are the main body of learning, and teachers play the role of guides and supporters. Students independently explore solutions to problems by consulting literature, experimental verification and team discussions. For example, when designing a mechanical device, students need to study material properties, structural design and mechanical analysis by themselves, so as to cultivate independent thinking and problem-solving abilities[6].

2.3 Focus on cultivating students' innovative thinking and practical ability

The PBL model emphasizes cultivating students' practical ability through practical operation and innovative design. In the mechanical design course, students can apply theoretical knowledge to practical problems by designing and making mechanical models. For example, students can design an energy-saving mechanical device and verify its performance through experiments, thereby improving their innovation ability and engineering practice ability[7].

2.4 Improve students' communication skills and teamwork spirit through teamwork

The PBL model is usually carried out in groups, and students complete tasks through division of labor and collaboration. In the mechanical design course, students can work in groups to design a complex mechanical system, such as a robot or automated equipment. Each team member is responsible for a different module and solves problems through discussion and collaboration. This kind of teamwork not only improves students' communication skills, but also cultivates their spirit of collaboration[8].

The problem-oriented teaching model provides an effective teaching method for the basic mechanical design course design by driving real problems, emphasizing the subject status of students, cultivating innovative practical ability and promoting teamwork. This model not only improves students' learning interest and participation, but also cultivates their comprehensive ability, laying the foundation for adapting to the needs of modern engineering education[9-10].

3. Analysis on the current status of design teaching of basic mechanical design courses at Liaoning University of Science and Technology

3.1 Teaching content

The course content of the basic mechanical design course of Liaoning University of Science and Technology is outdated to a certain extent and fails to fully reflect the latest development of modern mechanical design technology. The specific manifestations are:

Traditional content accounts for too high a proportion: The course design is still mainly based on

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classic content such as traditional mechanical transmission (such as gear transmission, belt transmission), shaft structure design, etc. Although these contents are basic, they are not closely related to the practical application of modern mechanical design.

Insufficient coverage of cutting-edge technologies: Cutting-edge technologies such as finite element analysis, reverse engineering, parametric modeling, and topology optimization, which are widely used in modern mechanical design, are rarely covered in the course, making it difficult for students to access the latest technologies and tools in the industry.

Case updates are lagging behind: Course design cases are mostly classic cases, and lack the introduction of actual engineering projects in modern industry (such as intelligent manufacturing, robot design, etc.), resulting in students' insufficient understanding and ability to solve actual engineering problems.

3.2 Teaching methods

The teaching method is relatively simple, mainly based on teacher lectures, lacking interactivity and active participation of students:

Teacher-led teaching: Teachers mainly explain theoretical knowledge and demonstrate standardized design cases in class. Students passively accept knowledge and lack the cultivation of independent exploration and critical thinking.

Lack of interactive communication: There is little interaction between teachers and students in class, student participation is not high, and there is a lack of interactive links such as group discussion and case analysis, which makes it difficult to stimulate students' interest and initiative in learning.

Traditional teaching methods: The teaching methods are relatively traditional, mainly relying on textbooks and PPT, and lack the use of modern teaching tools such as multimedia teaching and virtual simulation.

3.3 Practical teaching

The practical teaching link is relatively weak, and students' hands-on ability and engineering practice ability are insufficient. Specifically:

Outdated experimental equipment: The updating of laboratory equipment lags behind, and students cannot access industrial-grade design software (such as SolidWorks, ANSYS) and real engineering cases in experiments, resulting in a separation between theory and practice.

Insufficient design of practical links: The practical links in the course design are mostly simple design tasks, lacking comprehensive and innovative practical projects, making it difficult for students to improve their practical operation skills through practical links.

Lack of real engineering background: Practical teaching content is mostly simulation experiments, lacking real engineering background, making it difficult for students to apply what they have learned to actual engineering projects.

3.4 Assessment and evaluation

The assessment method is relatively simple, mainly based on the final exam results, and lacks a comprehensive evaluation of the students' learning process:

Single assessment method: The current assessment is mainly based on design drawings and instructions, ignoring the comprehensive evaluation of students' design process, teamwork and innovation ability, making it difficult to motivate students to deeply participate in course learning.

Insufficient process evaluation: There is a lack of evaluation of students' daily learning process, such as regular homework, project reports, group discussions, etc., which cannot fully reflect the students' learning effects.

The evaluation criteria are not comprehensive enough: the assessment criteria mainly focus on the design results, but lack the evaluation of students' soft skills such as innovation and teamwork ability in the design process.

Specific application cases

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To solve the above problems, the School of Mechanical Engineering of Liaoning University of Science and Technology introduced the problem-based teaching model (PBL) in the design of the basic mechanical design course, and designed the "Design and Optimization of Intelligent Robot Arm" project. The following are the specific implementation steps and results of the project:

Project Background

With the rapid development of intelligent manufacturing technology, the design and optimization of robotic arms, as key equipment in automated production lines, has become a research hotspot in the field of mechanical engineering. Under the traditional teaching model, students have limited understanding of the design principles and practical applications of robotic arms, and lack systematic design and optimization capabilities. To solve this problem, the School of Mechanical Engineering at Liaoning University of Science and Technology introduced the PBL model in the design of the basic mechanical design course, and through the "Design and Optimization of Intelligent Robot Arms" project, cultivated students' engineering practice ability and innovative thinking.

3.5 Implementation steps

3.5.1 Project import

Teacher guidance: The teacher introduces the application background of robotic arms in industrial production to students, shows actual case videos and pictures, and stimulates students' interest in learning.

Problem statement: The teacher raises a design question, such as "How to design an intelligent robotic arm that can complete specific tasks (such as grasping, carrying, and assembly)?" and lists the design requirements and constraints.

3.5.2 Team building and division of labor

Grouping: Students form teams freely, with 45 people in each group, ensuring that each group member has different professional backgrounds and skills.

Division of labor: Each group of students will be divided into different tasks according to their own strengths, such as structural design, kinematic analysis, control algorithm development, simulation and optimization, etc.

3.5.3 Knowledge learning and solution design

Self-directed learning: Students learn about robotic arm design by reading literature, watching online courses, and using simulation software.

Scheme design: Each group discusses and proposes a preliminary design scheme, including the structural form of the robotic arm, degree of freedom selection, drive mode, etc.

3.5.4 Design and Development

Structural design: Use CAD software such as SolidWorks to perform three-dimensional modeling of the robotic arm and optimize structural parameters.

Kinematic analysis: Use MATLAB/Simulink to perform forward and inverse kinematic analysis of the robotic arm to verify the feasibility of the design.

Control algorithm development: Develop motion control algorithms based on PID control to ensure precise operation of the robotic arm.

3.5.5 Mid-term evaluation and feedback

Progress Check: Teachers regularly check the progress of each group and provide technical guidance and suggestions.

Problem feedback: Students report the problems they encounter, and the teacher organizes a class discussion to jointly find solutions.

3.5.6 Results display and summary

Physical production: Each group makes a physical model of the robotic arm and conducts functional testing.

Report presentation: Each group of students presents their design results, including design reports,

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simulation videos and physical demonstrations.

Summary and evaluation: The teacher comments on the designs of each group, and the students reflect on the shortcomings in the design process and propose improvement plans.

3.6 Achievements

3.6.1 Improve knowledge and skills

Students mastered the basic principles and methods of structural design, kinematic analysis and control algorithm development of robotic arms.

Proficient in using engineering software such as SolidWorks, MATLAB/Simulink, etc., which has improved digital design capabilities.

3.6.2 Teamwork skills

Through teamwork, students learned how to divide work, cooperate, communicate and coordinate, and enhanced their team awareness.

In the process of solving practical problems, students' communication skills and teamwork spirit are significantly improved.

3.6.3 Innovative thinking

Each team proposed a variety of innovative solutions in the design, such as lightweight structure design and adaptive grasping algorithms.

Students' innovative thinking and problem-solving abilities are exercised, and they are able to complete complex design tasks independently.

3.6.4 Comprehensive quality

After completing the project, students have a deeper understanding of the theoretical knowledge and practical applications of mechanical design.

Students' engineering practice ability, comprehensive quality and employment competitiveness have been significantly enhanced.

Through the "Design and Optimization of Intelligent Robotic Arms" project, Liaoning University of Science and Technology successfully transformed its mechanical design course from the traditional teaching model to the PBL model. In the project, students not only mastered the basic principles of mechanical design, but also improved their teamwork ability and innovative thinking, laying a solid foundation for their future career development.

4. Specific measures for teaching reform

4.1 Introduce actual engineering cases

Select actual engineering cases related to mechanical design to guide students to analyze and solve problems, and improve their engineering practice ability and innovative thinking. For example:

Case selection: We select actual engineering cases such as “Design and optimization of intelligent robotic arms” and “Design of automated production lines” to demonstrate the complexity and diversity of actual engineering problems.

Case analysis: Organize students to analyze problems in cases, propose solutions, and deepen their understanding of mechanical design principles through discussion and communication.

4.2 Adopt project-driven teaching method

Using projects as a carrier, students can master the basic principles and methods of mechanical design in the process of completing projects, and cultivate their teamwork spirit and innovation ability. For example:

Project Design: Design the "Design and Optimization of Intelligent Robotic Arm" project, requiring students to complete the structural design, kinematic analysis and control algorithm development of the

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robotic arm.

Project implementation: Students are divided into groups to complete project tasks, solve practical problems through teamwork, and improve their engineering practice and innovation capabilities.

4.3 Conduct group discussions and collaborative learning

Organize students to conduct group discussions and cooperative learning, promote communication and interaction among students, and improve students' communication skills and teamwork spirit. For example:

Group Discussion: Group discussions are organized regularly for students to share their research progress and discuss problems encountered and solutions.

Collaborative learning: Complete project tasks through teamwork to enhance students' teamwork spirit and communication skills.

4.4 Use modern educational technology

With the help of modern educational technologies such as multimedia teaching and online teaching platforms, we can enrich teaching resources and improve teaching effects. For example:

Multimedia teaching: Use multimedia resources such as PPT, video, animation, etc. to enhance the intuitiveness and fun of teaching.

Online teaching platform: Use the online teaching platform to publish teaching materials, assign homework, organize discussions, and improve the interactivity and flexibility of teaching.

4.5 Strengthen practical teaching

Increase practical teaching links such as experimental teaching, course design, internship, etc. to provide students with more hands-on opportunities and cultivate students' engineering practice ability. For example:

Experimental teaching: Introduce modern experimental equipment and virtual simulation platforms, such as SolidWorks, ANSYS, etc., so that students can come into contact with real engineering problems in experiments.

Course Design: Design comprehensive and innovative course design projects, such as “Design and Optimization of Intelligent Robotic Arms”, to enable students to improve their engineering practice ability through practical operation and design.

Internship activities: Cooperate with enterprises to organize students to practice at actual production sites to understand the application of mechanical design in actual engineering.

5. Practical Effects of Teaching Reform

By implementing the problem-oriented teaching model in the design of the basic mechanical design course, the following significant results have been achieved:

5.1 Students’ enthusiasm and initiative in learning have been significantly improved

Enhanced classroom participation: Students' participation in class has significantly improved. They actively ask questions and discuss, and the learning atmosphere has become more active.

Improvement of autonomous learning ability: Students have improved their autonomous learning and problem-solving abilities by consulting literature and using simulation software.

5.2 Students’ innovation and practical abilities have been significantly improved

Independently complete design projects: Students are able to independently complete some simple mechanical design projects, such as “Design and Optimization of Intelligent Robot Arms”, demonstrating strong innovation and practical abilities.

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Propose innovative solutions: Each group proposed a variety of innovative solutions in the design, such as lightweight structure design, adaptive grasping algorithm, etc., which reflects the students' innovative thinking.

5.3 Students' teamwork spirit and communication skills are exercised

Enhanced teamwork ability: By completing project tasks through teamwork, students learned how to divide labor, cooperate, communicate and coordinate, and enhanced their team awareness.

Improved communication skills: In group discussions and project reports, students' communication and expression skills have been significantly improved.

5.4 The students' engineering practice ability and comprehensive quality are recognized by employers

Enhanced engineering practice ability: Students demonstrate strong engineering practice ability during internships and employment and are able to quickly adapt to the actual working environment.

Improvement of comprehensive quality: The comprehensive quality and employment competitiveness of students have been significantly enhanced, and are highly recognized by employers.

6. Conclusion

The application of problem-oriented teaching mode in the design of basic mechanical design courses has effectively solved the problems existing in the traditional teaching mode and improved the teaching quality and students' learning effect. By introducing actual engineering cases, adopting project-driven teaching methods, conducting group discussions and cooperative learning, using modern educational technology, and strengthening practical teaching links, we have cultivated students' innovative and practical abilities and provided the society with more high-quality application-oriented engineering and technical talents. In future teaching reforms, we will continue to explore and improve the problem-oriented teaching mode, continuously improve the teaching quality, and contribute to the cultivation of more outstanding engineering and technical talents.

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