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Exploration of Inquiry-Based Teaching Method in the Marine Diesel Engine

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Abstract

The marine diesel engine course is a highly theoretical subject with complex and diverse systems, requiring extensive practical training. In response to the existing issues in the current teaching process of marine diesel engine courses, this paper proposes an innovative approach to reform by applying the heuristic inquiry-based teaching method to marine diesel engine courses. Practice has shown that this teaching method has the advantages of stimulating learning enthusiasm, strengthening theoretical understanding, cultivating comprehensive literacy, and aligning with training objectives. It has important practical significance for improving students' professional literacy and cultivating high-quality talents that meet the needs of the times.

Keywords

Inquiry-based teaching method; Marine diesel engine; Teaching reform.

1. Introduction

The course content of Marine Diesel Engines mainly includes the basic knowledge, working principles, structure of fixed parts, structure of moving parts, lubrication system, fuel system, cooling system, etc., of diesel engines. It is characterized by both strong theoretical and practical nature [1]. As a position-oriented course in the talent training system, it plays an important role in cultivating the professional competencies required for corresponding jobs.

2. Problems in Marine Diesel Engines Teaching

Marine Diesel Engines are the "heart" of ships and boats. Their working principles, structural composition and characteristics, maintenance and management methods, as well as fault diagnosis and troubleshooting capabilities are the basic knowledge and important skills that students must master. Under the traditional teaching mode, the teaching of the Marine Diesel Engines course usually adopts a simple linear model of "teachers lecture and students listen". The teaching content focuses on theoretical analysis and structural identification, while the teaching methods are tedious and single, which easily leads to the phenomenon of "separation between theory and practice". Students passively accept knowledge and often fail to apply abstract theoretical knowledge to solve practical problems in the ship's engine room, suffering from the common problem of "understanding but not being able to use". Therefore, it is imperative to change the outdated teaching methods and explore a teaching mode that can stimulate students' motivation for active learning, and cultivate their comprehensive inquiry ability and practical problem-solving ability.

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3. Theoretical Connotation and Applicability of the Heuristic-Inquiry Teaching Method

3.1. Theoretical Connotation

The heuristic-inquiry teaching method organically integrates the advantages of "heuristic teaching" and "inquiry-based learning". By purposefully designing problem scenarios, teachers inspire students to think, guide them to actively explore, acquire knowledge, as well as discover and solve problems [2]. It shifts the focus of learning from teachers to students, which conforms to the requirements of practicality and creativity in engineering education and teaching. The heuristic-inquiry teaching method is not a simple superposition of heuristics and inquiry, but an organic whole. Its theoretical basis is rooted in constructivist learning theory, discovery learning theory and the concept of Problem-Based Learning (PBL). Constructivism holds that knowledge is not obtained through passive indoctrination by teachers; instead, learners acquire it through meaning construction in specific scenarios with the help of others (teachers and learning partners) and the use of necessary learning materials [3]. Precisely by creating real or simulated engineering scenarios (such as fault phenomena), heuristic-inquiry teaching guides students to actively construct the knowledge system related to the working principles of diesel engines.

3.2. Applicability in the Marine Diesel Engines Course

The content of the Marine Diesel Engines course, such as working processes, characteristic analysis, system composition (including fuel system, lubrication system, cooling system, etc.) and fault diagnosis, is inherently a system full of logical relationships and causal chains. These contents are highly suitable for exploration with "problems" as the entry point. For example, targeting the common phenomenon of "diesel engine emitting black smoke", a series of inquiry-based questions can be raised: What is the composition of black smoke? What are the fundamental conditions for its generation? Which systems of the diesel engine are involved (fuel injection, intake supercharging)? What are the possible specific causes (poor atomization of injectors, clogged air filters, etc.)? How to troubleshoot them one by one? This series of questions naturally forms a complete inquiry chain, which is very suitable for the application of the heuristic-inquiry teaching method.

4. Application Practice of the Heuristic-Inquiry Teaching Method in the Marine Diesel Engines Course

Taking the typical teaching module of "Fault Diagnosis of Diesel Engine Fuel Injection System" as an example, this section elaborates on the four-stage application process of the heuristic-inquiry teaching method.

4.1. Creating Authentic Problem Situations to Stimulate Inquiry Desire

Instead of directly explaining the components of a system as before, teachers play a video of a real ship or simulator malfunction—where a ship's engine lacks power during acceleration and emits black smoke from the exhaust pipe. The teacher then poses several guiding questions: "Class, if you were the mechanical and electrical personnel in charge of this ship, what would you do first when you see this situation? Where do you think the problem might lie?" This problem, derived from real engineering practice, immediately immerses students in the role of mechanical and electrical staff, fostering a stronger sense of responsibility to solve the problem and arousing their interest in learning.

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4.2. Guiding Independent Inquiry and Building a Knowledge Framework

When students put forward initial ideas such as “there is a problem with the fuel injector” or “insufficient air intake,” the teacher does not immediately judge whether these ideas are correct or directly provide the right answer. Instead, the teacher transforms into a designer of learning resources and a guide for the inquiry process. The teacher prepares professional inquiry tools and a wealth of learning materials for students, and leads them to carry out an independent inquiry activity centered on the problem in groups. The tasks of this inquiry activity are carefully designed, with each link closely connected, aiming to guide students from theoretical knowledge in textbooks to practical operation, and from superficial phenomena observed to the essential principles behind them. The specific inquiry tasks are divided into three progressive stages.

4.2.1. Reviewing Theory and Consolidating the Foundation

Before students begin to analyze the problem, they first review the relevant core theoretical knowledge. For example, they need to understand how a diesel engine injects fuel—details such as how the high-pressure fuel circuit delivers fuel and when fuel injection starts. In addition, the precise structure of the fuel injector cannot be overlooked: the needle valve that controls injection, the pressure chamber that stores fuel, and the small orifices through which fuel is sprayed—each with its own working principle that must be clarified. Of course, for fuel to burn well in the cylinder, certain conditions must be met: an appropriate air-fuel ratio, sufficiently uniform mixture, and the required temperature and pressure inside the cylinder. This step essentially activates students’ prior knowledge and helps them build a solid conceptual framework. By connecting these theoretical points, they can analyze specific problems more systematically later on.

4.2.2. Analyzing Information and Establishing Connections

After completing the theoretical review, each group acts as a "technical detective" by consulting reference materials such as textbooks, professional technical manuals, and maintenance databases. Their core task is to analyze and integrate this information, focusing on how key parameters—including fuel injection pressure, injection timing advance, and fuel atomization quality—specifically affect combustion completeness, efficiency, and cleanliness. Through this stage, students gradually learn to extract useful information from a large volume of technical literature, connect different pieces of information, and analyze content with a critical perspective.

4.2.3. Virtual Simulation for Verification and Exploration

To connect textbook theory with real-world phenomena, students use specialized diesel engine process simulation software for experiments. In a computer-simulated environment, they can repeatedly adjust various fuel injection parameters mentioned by the teacher—such as injection pressure and injection timing advance—without worrying about risks from operational errors or incurring excessive costs. Each adjustment is immediately reflected in the software’s display of changes in diesel engine output power, torque, fuel consumption, and other parameters. Following the step-by-step process of “hypothesize first, then verify, observe changes, and analyze causes,” students can clearly see how different parameters interact and how these interactions affect the overall performance of the diesel engine.

Through such a complete inquiry process, students’ learning identity undergoes a significant transformation. Previously, they were merely passive recipients of knowledge from teachers; now, they have become active information seekers, problem analysts working with peers, and proactive problem solvers. During the inquiry process, they either verified their initial ideas or discovered that their previous assumptions were incorrect and revised them accordingly. More importantly, through active exploration and hands-on operation, they reorganized theoretical knowledge such as “fuel injector structure” and “combustion optimization,” gaining a deeper

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understanding and learning how to apply these concepts in practice. This transforms knowledge from "being memorized" to "being truly understood," and finally to "being operable in practice." Such a problem-centered, process-oriented learning approach helps students develop engineering thinking, learn to collaborate with others, and enhance their comprehensive ability to solve complex technical problems.

4.3. Collaborative Discussion and Teacher's Focused Explanation for Knowledge Internalization

Each group discusses the results obtained from their inquiry, analyzes the data recorded in experiments together with the phenomena observed in simulations, and finally compiles a fault analysis report for the group. They also develop a step-by-step troubleshooting plan, and then share their findings with the whole class. Some groups may conclude that the fault mainly lies in the fuel injector, while others, based on their simulations and learned theories, attribute the problem to the air system—each with their own reasoning. Such divergent viewpoints actually provide a valuable opportunity for students to learn more deeply. At this point, the teacher is no longer merely a provider of materials, but a guide who leads students to think about more complex issues and helps them connect and clarify the knowledge they have acquired. The teacher's guidance is mainly reflected in the following two aspects.

4.3.1. Guiding Discussion and Focusing on Methodology

Instead of immediately judging students' viewpoints, the teacher uses questions to guide them from mere argumentation to reflection on their argumentation methods. For example, when organizing a debate, the teacher might ask: "What evidence supports your respective viewpoints? Can you design a practical, step-by-step verification procedure to prove your claims?" Such guidance prompts students to think about how to define variables, sequence tests, and select appropriate tools, transforming subjective guesses into engineering-logic-based verification plans.In this process, students no longer focus only on what their viewpoints are, but also on how to prove them. They gradually develop a diagnostic mindset and learn to troubleshoot problems using a systematic approach.

4.3.2. Refined Guidance to Construct a Knowledge System

After students engage in thorough discussions, the teacher provides targeted guidance on common doubts and poorly grasped knowledge points. For example, in terms of fuel system fault diagnosis, the teacher helps students organize scattered ideas into a clear logical framework; regarding the use of fuel injector test benches, the teacher elaborates on their working principles and inspection procedures in detail. In this way, the fragmented knowledge students previously acquired can be gradually connected to form a complete knowledge system.

4.4. Achieving Knowledge Transfer and Promoting Innovative Application

The purpose of learning lies in application. Teachers can set more challenging inquiry tasks to drive the transfer and application of knowledge.

4.4.1. Scheme Verification

On the diesel engine training bench, students put their self-designed troubleshooting schemes into practice to verify the diagnostic results.

4.4.2. Creating New Situations

Problems close to real-world scenarios can be designed, such as: "If a diesel engine experiences severe vibration during operation and a knocking sound is heard, what might be the problem? How can it be identified step by step?"

Such questions enable students to apply the fuel system inquiry approaches they have learned to mechanical fault troubleshooting. For example, the disassembly inspection and parameter comparison methods used earlier to analyze fuel injector clogging can also be applied to

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diagnosing mechanical issues like excessive piston clearance. In many cases, the troubleshooting logic across different systems is similar; the key lies in the flexible transfer and application of learned methods.

4.4.3. Guiding Innovation

Teachers can guide students to reflect on two specific questions: first, what aspects of the fuel system can be improved; second, how to reduce pollutant emissions and fuel consumption of diesel engines through these improvements. Discussions on such questions help students gradually develop the habit of proactively seeking new methods and approaches in their thinking process. For example, after these questions are raised in class, students may start with details such as fuel injection timing and pressure, proposing different improvement directions—these thinking processes themselves embody the awareness of innovation.

5. Teaching effect evaluation and reflection

5.1. Diversified Evaluation System

To align with the heuristic inquiry-based teaching model, it is imperative to reform the single paper-based assessment method and establish a diversified evaluation system that integrates formative and summative evaluations [4]. Specifically, formative evaluation accounts for 60% of the total score, whereas summative evaluation accounts for 40%. Formative evaluation encompasses multiple dimensions, including students' performance in the inquiry process (e.g., initiative and collaboration), the quality of research reports, the standard of group presentations, and the standardization of practical training operations. Summative evaluation comprises a final written examination and a practical operation assessment: the former focuses on assessing students' comprehension of core theories and their capability to apply these theories to address comprehensive problems, while the latter primarily evaluates their proficiency in key professional skills.

5.2. Application Effects and Advantages

5.2.1. Stimulating Learning Initiative

It transforms students from "passive learners" into "active knowledge seekers", resulting in a significant increase in their classroom participation and a marked upsurge in their enthusiasm for delving into knowledge after class.

5.2.2. Strengthening Theoretical Understanding

Knowledge acquired through inquiry-based learning is not only firmly retained by students but also thoroughly comprehended, enabling them to flexibly apply it in practical scenarios.

5.2.3. Cultivating Comprehensive Literacy

In the series of practices from problem discovery and analysis to resolution, students' practical engineering operation capabilities are effectively enhanced. In most cases, a single project cannot be completed by an individual alone; the process of discussing plans collectively and dividing tasks for collaboration also contributes to the gradual improvement of their team cooperation abilities.

5.2.4. Aligning with Training Objectives

This teaching method closely links classroom knowledge explanation with practical operations in the engine room. The talents cultivated can directly meet the current needs of positions, while having sufficient room to adapt to future changes in the industry.

5.3. Challenges and Reflections in the Implementation Process

The heuristic inquiry-based teaching method still faces numerous problems to be addressed in practical application. For instance, this teaching method imposes higher requirements on

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teachers' capabilities: teachers must not only possess rich teaching experience but also flexibly control classroom rhythm and respond to various questions raised by students at any time. In addition, the teaching process requires sufficient support from practical training resources, such as simulation software and experimental benches for students to conduct hands-on practice; insufficient resources will compromise the teaching effect. Furthermore, it is difficult to control the teaching progress—sometimes, due to the varying depths of students' inquiry, the original teaching plan may be disrupted. In response to these situations, schools can cultivate more "double-qualified teachers" who are capable of both teaching theoretical knowledge and guiding practical operations. Meanwhile, more funds should be invested in constructing practical training venues and adding practical training equipment. Additionally, the "hierarchical and progressive" approach can be adopted: first, apply this teaching method intensively in the core modules of the course, and then gradually promote it to other modules after teachers and students have adapted to it.

6. Conclusion

The adoption of the heuristic inquiry-based teaching method in the Marine Diesel Engine course represents a reform of the traditional teaching model. Taking practical problems as the starting point, this method encourages students to conduct independent exploration and research, with teachers providing guidance alongside, gradually transforming the classroom into a platform that integrates theory with practice and emphasizes both knowledge and capabilities. In such a classroom, students can not only solidly master the key knowledge and operational skills of marine diesel engines but also gradually develop the habit of critical thinking, with enhanced abilities to identify problems independently and solve complex engineering challenges. From the perspective of talent cultivation, it holds practical value for improving students' professional competence and nurturing talents that meet the demands of the times.

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