*Review*

# Regarding the Current Situation of Marine Power Plants in the Context of Digital-Intelligence Integration

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**Abstract:** With the implementation of the 'Maritime Power' strategy and rapid advancement of intelligent ship technology driven by global shipping industry's digital transformation, marine power plants are undergoing a comprehensive evolution from traditional mechanization to digitalization and intelligence. This technological transformation has fundamentally reshaped the talent requirements in maritime engineering, demanding enhanced professional competencies and practical abilities. Current practical teaching of marine power plants in domestic universities faces several critical challenges, including insufficient high-standard training resources, thereby misalignment between curriculum and industry needs, inflexible teaching methodologies, thereby and outdated evaluation systems unsuitable for intelligent talent development, hence this review systematically analyzes these challenges and proposes a comprehensive reform framework based on digital-intelligence integration principles and new engineering requirements, thereby the proposed solution encompasses three key components: first, the establishment of a virtual-physical interconnected digital twin experimental platform to overcome traditional laboratory constraints; second, the implementation of data-driven, industry-oriented practical teaching content aligned with enterprise requirements; and third, the development of an innovative human-machine collaborative teaching model that seamlessly integrates physical operations with digital simulations. This integrated approach aims to cultivate a new generation of maritime engineering professionals equipped with robust technical foundations, advanced digital-intelligence capabilities, and practical problem-solving skills essential for the intelligent shipping era. The framework presented provides a strategic roadmap for educational institutions to effectively support China's evolving shipbuilding and shipping industry through enhanced talent development programs.

**Keywords:** Marine power plants; digital twin technology; maritime engineering education; intelligent shipping systems; practical engineering training; digital transformation

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## 1. Introduction

Marine power plants serve as the essential core of various types of ships, including cargo vessels, passenger liners, and specialized engineering ships. The operational reliability, energy efficiency, and intelligent functioning of these power plants are crucial for ensuring the safety of navigation. This enhancing the economic performance of shipping enterprises, and and adhering to international marine environmental protection standards, thereby in recent years, thereby the integration of advanced information technologies such as big data, artificial intelligence, the Internet of Things, cloud computing, and and digital twin technology with the traditional shipbuilding and maritime sectors has ushered the global shipping industry into a pivotal phase of intelligent and eco-friendly transformation [1]. This transformation is characterized by the adoption of cutting-edge technologies, including intelligent engine rooms, predictive health management systems for equipment, online energy efficiency monitoring and early warning systems. Remote fault diagnosis platforms. And unmanned ship power control systems. These innovations have transitioned from being subjects of technical research to practical applications, becoming standard features and key competitive advantages of modern commercial vessels and marine engineering equipment, hence the shift towards these advanced technologies reflects a broader trend in the maritime industry towards enhancing operational efficiency and sustainability. Aligning with global efforts to reduce environmental impact and improve safety standards.

The rapid technological advancements in the maritime industry have fundamentally altered the traditional skill set required for marine engineering technicians. Historically, professionals in marine power plants were primarily required to understand mechanical principles, possess skills in equipment disassembly and assembly. And be adept at conventional operation and maintenance techniques. However, with the integration of digital and intelligent technologies. Modern marine engineering professionals must now possess a diverse range of interdisciplinary skills [2, 3]. They need to be well-versed not only in the structural and operational principles of traditional marine power equipment but also in data-related competencies such as data collection, transmission, cleaning, analysis, and and mining. Additionally, they must be proficient in applying intelligent algorithms, debugging intelligent systems, and making informed digital decisions. Furthermore, these professionals must be equipped to handle complex marine environments and address unexpected engineering challenges within a digital and intelligent framework, and this evolution in skill requirements underscores the need for a new breed of marine engineers who can seamlessly integrate traditional engineering knowledge with modern technological capabilities. This thereby enhancing the overall efficiency and safety of maritime operations.

The conventional practical teaching methods for marine power plants in educational institutions have struggled to keep pace with the evolving demands for new talent in the industry. Currently, hence the practical teaching in many domestic colleges and universities remains focused on basic physical equipment disassembly and assembly, offline static simulations. And isolated verification experiments, and this approach lacks the integration of real-time operational data from actual ship power plants and fails to provide targeted training in digital thinking, data analysis. And intelligent operation and maintenance practices. As a result. Students often acquire only surface-level operational skills without developing a comprehensive understanding of the relationship between equipment operation and data dynamics, thereby they also lack practical experience in managing complex and extreme working conditions [4, 5], and in light of the national strategy for 'new engineering' construction, and this emphasizes the cultivation of innovative and multidisciplinary engineering talents, hence there is an urgent need to leverage digital-intelligence technologies to enhance traditional marine engineering practical teaching. This involves overcoming the spatial and functional barriers between physical teaching environments and digital simulation spaces; and establishing a practical teaching system that integrates virtual and real elements, thereby is data-driven. And fosters intelligent collaboration. Addressing this challenge is crucial for advancing maritime education in China and ensuring that graduates are well-prepared to meet the demands of the modern maritime industry.

## 2. Current Status and Pain Points of Practical Teaching of Marine Power Plants

In recent years, there has been a notable increase in the focus of colleges and universities on enhancing the practical skills of engineering students. This has led to a significant rise in investments directed towards the development of professional laboratories dedicated to marine power plants, thereby these laboratories are now equipped with essential physical experimental equipment, some simulation software. And basic teaching aids, and despite these advancements; the practical teaching of marine power plants faces three major challenges that hinder the enhancement of teaching quality and the effectiveness of talent cultivation, and these challenges create a disconnect between the educational outcomes and the actual job requirements of shipping enterprises, as well as ship design and manufacturing units [2, 6]. The rapid evolution of the intelligent shipping industry further exacerbates these issues, highlighting the need for educational institutions to adapt and align their teaching methods with industry demands to ensure that graduates are well-prepared for the workforce [7].

*2.1. Limited Hardware Resources and Difficult Replication of High-Risk and Complex Working Conditions*

Marine power plant systems are notable for their substantial size, significant equipment costs, intricate structures. And stringent operational guidelines. These systems are also associated with high risks if not operated correctly [6, 8]. The complete set of marine power equipment encompasses a wide range of components. Including main engines, auxiliary engines, and boilers, and separators, various pump systems, pipeline networks, thereby and control cabinets, and these components span multiple disciplines such as mechanical, hence electrical, hydraulic. And control systems. The financial investment required for a full-scale set of marine power equipment can reach millions or even tens of millions of yuan. Additionally. The installation demands a large space and comprehensive safety facilities, making it challenging for university laboratories to replicate the real ship engine room environment and complete equipment configuration [7, 9]. Due to limitations in construction funding and available space, most college laboratories are only able to equip themselves with miniaturized, scaled-down, or outdated equipment for educational purposes. Consequently, the experimental projects conducted are primarily basic verification experiments that focus on structural understanding and simple operations. These projects often lack comprehensive and exploratory experimental content. This is essential for a deeper understanding of the systems (As shown in Figure 1).

**Figure 1.** Marine power plant

Furthermore, the extreme, high-risk. And complex working conditions that ships frequently encounter during marine navigation present additional challenges; situations such as a complete ship blackout due to power system failure; main engine runaway caused by fuel system anomalies, fires in the scavenge box due to unburned oil accumulation. Abnormal shafting vibrations under heavy sea conditions. And energy efficiency declines under variable load conditions are difficult to replicate on physical experimental platforms [5, 10]. This is primarily due to concerns for personnel safety and the protection of equipment. As a result, students often lack the opportunity to gain intuitive and practical experience in handling emergencies. This making fault judgments, hence and preventing risks under extreme conditions during their education. When these students transition into the workforce. They frequently find it challenging to quickly adapt to the actual ship working environment [6], and they may lack the ability to independently manage sudden faults and require extensive on-the-job training to meet the demands of their roles [7, 11]. This gap significantly reduces the efficiency of transitioning from academic education to employment in the industry.

*2.2. Single Teaching Methods and Serious Disconnection Between Teaching and Digital-Intelligence Technology*

Currently, the teaching methods employed in the practical training of marine power plants at higher education institutions are notably limited and inflexible. These methods are primarily categorized into two distinct types, each exhibiting significant shortcomings that contribute to a pronounced gap between the educational content and the advancements in digital-intelligence technology. The first type involves physical disassembly, assembly, and operational experiments conducted with real, small-scale equipment. This approach is designed to enhance students' practical skills and their understanding of equipment structures. However, it lacks the integration of real-time data collection, display, and analysis. Students are required to follow predetermined steps without the opportunity to observe dynamic data changes in parameters such as temperature, pressure, vibration, and and flow during equipment operation. Consequently. They are unable to establish a connection between their operational actions and the corresponding data outcomes; this limitation hinders their ability to comprehend the full scope of equipment functionality and the impact of their actions on performance metrics [3].

The second type of teaching method involves offline simulation training conducted in computer labs using engine room simulation software on personal computers [5, 12]; while this method can replicate certain aspects of ship engine room operations, it predominantly relies on simplified mathematical models and fixed operational logic. These limitations prevent the software from accurately representing the nonlinear, time-varying, and interdependent characteristics of actual ship power equipment under varying operational conditions. The simulation data is typically composed of preset, static values rather than real-time dynamic data generated from actual operations. This making it challenging to recreate the true operational state of the equipment. During the teaching process, students often focus solely on the correctness of operational steps, and such as ensuring valves are properly opened or pumps are correctly started. While neglecting the underlying sensor data logic and system operation mechanisms. For instance, students may understand the need to reduce load when exhaust temperatures are high but lack the skills to collect and analyze historical exhaust temperature data sequences. They are also unable to utilize data algorithms for predicting early failures in components like fuel injectors. This is crucial for intelligent fault diagnosis and predictive maintenance [13]. This results in a prevalent issue among students: they can perform mechanical operations but struggle with data analysis and the application of intelligent solutions. This is misaligned with the skill requirements of modern intelligent shipping enterprises [5].

*2.3. Lagging Evaluation System and Inability to Quantify Comprehensive Ability*

The current practical teaching evaluation system for marine power plants is notably outdated, characterized by a narrow evaluation scope and a pronounced focus on outcomes. This approach fails to comprehensively and objectively assess students' overall abilities and learning processes, and this making it challenging to meet the assessment needs associated with digital-intelligence literacy [14], and presently, most practical assessments emphasize the final operational outcomes, such as the successful initiation of an engine. Adherence to standardized disassembly and assembly procedures. And the timely completion of experimental reports [15]. This method of evaluation prioritizes the end result, neglecting the evaluation of students' inquiry processes during learning. Their analytical thinking regarding data, and their logical approach to fault analysis, their innovative problem-solving skills. And their ability to collaborate effectively in teams during practical exercises [5]. Such an approach does not capture the full spectrum of skills and competencies that are crucial in the modern educational landscape.

In the realm of digital and intelligent education, solving engineering problems related to marine power plants often involves multiple approaches and methodologies. Students' abilities to utilize data tools, apply intelligent algorithms, and optimize system designs vary significantly. However, the traditional evaluation methods, which rely on standardized scoring tables and focus solely on results, are inadequate for assessing these varied performances [11]. They fall short in evaluating students' digital literacy, data analysis capabilities, and proficiency in intelligent applications. Furthermore, the current evaluation system predominantly depends on subjective scoring by teachers, lacking objective data support and comprehensive tracking throughout the learning process [5, 8]. This reliance on subjective judgment results in evaluations that are often unfair and one-dimensional, failing to accurately represent students' true learning status and ability levels. Consequently, it does not provide the necessary feedback and guidance for targeted improvements in teaching and learning, which is essential for nurturing students' comprehensive quality and innovative capabilities.

## 3. Practical Teaching Reform Strategy Driven by "Digital-Intelligence Integration"

Addressing the three primary challenges inherent in traditional practical teaching, this paper aligns with the evolving trends of the intelligent shipping industry and the demands for cultivating new engineering talents [14]. It proposes the establishment of a comprehensive, systematic, thereby and innovative practical teaching framework centered around the integration of digital and intelligent technologies [8]. The reform strategy is implemented comprehensively across three key dimensions: the reconstruction of educational platforms, the iterative updating of content, hence and the innovation of teaching methods. This approach aims to achieve a profound integration of digital and intelligent technologies with the practical teaching of marine power plants [12]. The ultimate goal is to significantly enhance the quality of practical teaching and elevate the level of talent cultivation, ensuring that students are well-prepared to meet the future demands of the industry.

### *3.1. Platform Reconstruction---Constructing a "Virtual-Physical Interconnected" Digital Twin Experimental Platform*

The concept illustrated in the figure emphasizes the importance of overcoming the constraints associated with traditional practical teaching methods, and this is achieved by developing a digital twin experimental platform that facilitates a seamless interconnection between virtual and physical realms, enabling real-time interaction. This innovative approach effectively dismantles the barriers that traditionally existed between physical laboratories and standalone virtual simulation software. By doing so, it allows for a comprehensive two-way data interaction and functional integration between physical equipment and virtual models [15]; the platform is meticulously structured into three fundamental layers: the physical layer, the virtual layer, and the virtual-physical fusion interaction layer [8, 12], and together, these layers form a cohesive closed-loop teaching system that harmoniously integrates both reality and virtuality. Offering a more holistic educational experience (As shown in Figure 3).

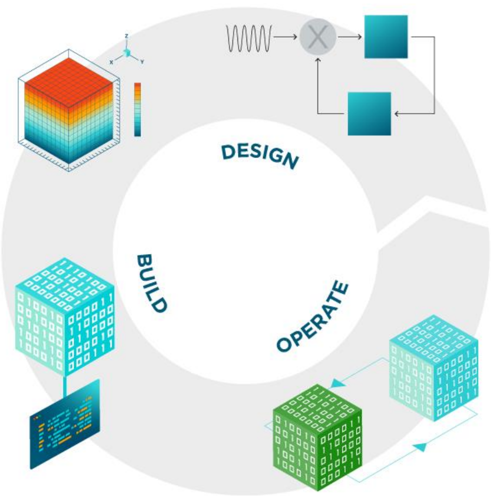


**Figure 3.** Integrated experimental platform for digital twin technology

In the physical layer; there is a focus on the intelligent enhancement and transformation of existing laboratory equipment such as diesel engines, auxiliary boilers, oil separators, and pump systems. This involves the installation of high-precision intelligent sensors designed to collect a variety of parameters including vibration; temperature, pressure, flow. And speed [8]. These sensors are paired with specialized data acquisition modules and data transmission terminals, facilitating the real-time collection, and precise transmission, thereby and digital display of the operational parameters of physical equipment [4]. This setup ensures the accurate digital mapping of the equipment's operational state; meanwhile, hence in the virtual layer, a high-fidelity 3D virtual engine room model is developed using advanced game development engines like Unity3D or Unreal Engine. This model meticulously replicates the layout, structure, pipeline connections. And appearance of a real ship engine room; additionally, a mechanism model is constructed using Matlab/Simulink to match the physical equipment, enabling the virtual model to not only visually replicate but also simulate the dynamic operational characteristics and fault response behaviors of real equipment [9].

The virtual-physical fusion interaction layer is designed to facilitate two-way real-time data interaction and operational linkage between physical benches and virtual platforms. This allows for the conversion of students' manual operations on the physical bench, such as throttle adjustments, valve operations, and equipment switching, hence into data signals that are transmitted to the virtual platform in real time. These signals drive synchronous changes in the virtual ship's navigation attitude, equipment operational state, and parameter performance, and conversely, and the virtual environment can simulate various scenarios such as different sea conditions, load changes, and fault situations, including increased wind and wave resistance, sudden equipment failures, hence and variable cargo loads [10], and these scenarios feed data back to the physical bench in real time, automatically adjusting the load of the physical loading device to simulate the real operational response of the equipment. This interconnected platform provides students with a safe environment to experience the real-world characteristics of ship-engine-propeller matching. Dynamic responses under challenging conditions. And fault handling processes. Effectively compensating for the limitations of traditional physical laboratories that are unable to simulate high-risk scenarios.

### *3.2. Content Iteration---Integrating "Data-Driven" Intelligent Operation and Maintenance Projects*

Building upon the digital twin experimental platform, there is a need to completely overhaul the practical teaching content related to marine power plants. This involves moving away from the traditional teaching model that primarily emphasizes structural understanding and basic mechanical operations. Instead, the focus should shift towards incorporating a higher proportion of data-driven, exploratory, and innovative practical projects [11]. This transformation ensures that the teaching content is closely aligned with the current and evolving needs of the industry. By doing so, students are better prepared to meet the demands of the modern workforce, where data literacy and innovative problem-solving are paramount. The integration of these elements into the curriculum not only enhances the educational experience but also bridges the gap between academic learning and practical industry requirements.

Initially, and it is crucial to enhance the training related to data collection and processing skills, and students should be guided to develop basic data acquisition and processing programs using tools such as Python or LabVIEW graphical programming software. This enables them to directly access and interpret the raw sensor data from the experimental setups. They should learn to perform essential data preprocessing tasks, including noise reduction, filling in missing values; and eliminating outliers; mastering these basic data analysis techniques is vital for cultivating students' proficiency in data engineering and fostering a digital mindset from the outset [11]. Furthermore, the introduction of intelligent fault diagnosis and predictive maintenance technology into the teaching framework is essential. By collaborating with classification societies and shipping enterprises, and real-world, desensitized data from ship power plant operations and fault cases can be incorporated into the curriculum. This allows for the design of targeted practical projects, and such as diagnosing shafting faults through vibration spectrum analysis, monitoring fuel injector leakage using exhaust temperature data, and predicting hidden main engine faults with machine learning algorithms. This approach encourages students to move beyond traditional experience-based maintenance methods and adopt a more analytical mindset, and by utilizing classic machine learning algorithms like support vector machines and random forests. Students can develop fault classification and prediction models, facilitating a shift from reactive maintenance to a more proactive, condition-based predictive maintenance approach [5, 13].

Moreover, it is important to integrate concepts of green shipping and energy efficiency optimization into practical teaching [3]. By aligning with international shipping energy efficiency regulations, such as the Energy Efficiency Design Index and the Energy Efficiency Existing Ship Index, practical projects focused on energy efficiency management and optimization can be established, and students can utilize the digital twin platform to conduct tests and gather data on fuel consumption, power output, and emissions under varying conditions of speed, cargo load. And trim [14]. This data analysis helps in understanding the impact of different operational parameters on energy efficiency, enabling students to identify the optimal operating conditions for the system. Through this process, students develop an awareness of green shipping practices and enhance their ability to optimize operations intelligently; by reconstructing the teaching content in this manner, students acquire the core skills necessary for careers in intelligent shipping, ensuring a seamless transition from academic learning to practical application in the industry [6].

### *3.3. Digital-Intelligence Reshaping of Teaching Evaluation System*

Utilizing the advanced capabilities of the digital twin experimental platform alongside an intelligent teaching management system. There is a significant opportunity to completely transform the traditional practical teaching evaluation system. This transformation involves establishing a comprehensive evaluation system that is full-process, multi-dimensional, data-driven, hence and intelligent [14]. The aim is to shift from a narrow focus on "single result assessment" to a broader "full-process comprehensive capability portrait." This approach ensures that the evaluation results are not only more objective but also more comprehensive and specifically targeted. This thereby enhancing the overall effectiveness and accuracy of the teaching evaluation process.

#### 3.3.1. Full-Process Digitalized Recording and Objective Data Assessment

A comprehensive digital tracking and recording module is developed based on an advanced intelligent teaching platform, and this module is designed to automatically gather and document all lifecycle data of students engaged in both virtual simulations and physical practical operations, and the data collected encompasses various aspects such as the duration and quality of pre-class preparation, the sequence and accuracy of steps taken during practical exercises, the frequency of errors and the proactive measures taken to correct them. The response time in decision-making during fault management, the quality of code written for data analysis. And the effectiveness of collaboration in team projects. Unlike traditional methods that rely on subjective scoring, this system ensures that all evaluation data are generated and recorded automatically, hence this providing a high degree of objectivity and authenticity [3, 9], thereby for instance, in a fault troubleshooting practical project, the system not only assesses whether students successfully resolve the fault but also meticulously records the sequence in which students check parameters, the logic applied in fault analysis, the time taken to identify issues, hence and the methods employed for solutions, and it then assigns objective process scores based on the rationality and coherence of the operational logic, thereby achieving a comprehensive assessment of students' practical learning experiences.

#### 3.3.2. Multi-Dimensional Capability Portrait and Personalized Feedback Guidance

The radar chart evaluation model is employed to construct a multi-dimensional comprehensive evaluation index system; this emphasizes five essential dimensions of student capabilities, thereby these dimensions include "hands-on operational ability," which assesses the practical skills students demonstrate in executing tasks; "data analysis and processing ability," which evaluates their proficiency in interpreting and managing data; "engineering logical thinking ability," which measures their capacity for systematic and analytical reasoning in engineering contexts; "team collaboration spirit," which examines their effectiveness in working collaboratively within groups; and "safety and regulatory awareness," which considers their understanding and adherence to safety protocols and regulations [3], hence upon the completion of each practical project, the system automatically calculates scores for each dimension based on the collected comprehensive data throughout the process. This results in the generation of a personalized capability radar chart. Forming a detailed portrait of each student's comprehensive capabilities, hence this evaluation approach not only aids educators in accurately identifying each student's learning status and areas needing improvement; this allowing for targeted adjustments in teaching strategies and content, but also empowers students to gain a clear understanding of their own strengths and weaknesses. Consequently, students can identify areas for improvement and engage in focused independent learning and training. Additionally, the evaluation system provides personalized teaching feedback and improvement suggestions for each student, thereby integrating evaluation with teaching, hence this integration fosters the continuous enhancement of teaching quality and learning outcomes, ensuring that both educators and students benefit from a more tailored educational experience.

## 4. Conclusion

Digital-intelligence integration is not only an inevitable trend of technological development in the global shipbuilding and shipping industry, but also a necessary path for the practical teaching reform of marine power plants under the background of new engineering construction, thereby the traditional practical teaching mode has been difficult to adapt to the demand for intelligent and compound maritime talents, hence and the problems of limited hardware resources, single teaching methods. And lagging evaluation systems have become key obstacles to improving the quality of talent cultivation, and by building a virtual-physical interconnected digital twin experimental platform, introducing real-time dynamic data streams and actual fault cases of the industry into the whole process of practical teaching, reconstructing data-driven practical teaching content. And innovating a full-process multi-dimensional digital-intelligence evaluation system, we can effectively solve the pain points of traditional teaching such as the inability to simulate high-risk and difficult scenarios, the disconnection between teaching and industry, thereby and the insufficient cultivation of digital-intelligence ability. This approach not only addresses the immediate challenges but also sets a precedent for future educational frameworks, ensuring that the next generation of maritime professionals is well-equipped to handle the complexities of modern shipping environments. The integration of digital intelligence into teaching practices represents a paradigm shift that aligns educational outcomes with industry needs. This fostering a more seamless transition from academic settings to professional environments.

The practice of teaching reform has proved that this digital-intelligence integrated practical teaching model can significantly stimulate students' learning interest and initiative, effectively improve students' hands-on operation ability, hence data analysis ability, and ability to solve complex engineering problems. And cultivate students' digital literacy and innovative thinking that meet the needs of the intelligent shipping era. In the future, hence we will further optimize the functions of the digital twin experimental platform, deepen the cooperation with shipping enterprises and classification societies, update the practical teaching content in a timely manner according to the technological iteration of the industry, thereby and continuously improve the practical teaching system of marine power plants. This reform will provide a replicable and promotable model for the practical teaching reform of marine engineering majors in domestic colleges and universities, and provide strong talent support and intellectual guarantee for cultivating high-quality compound engineering and technical talents for the intelligent shipping and maritime power construction. Moreover. The ongoing evolution of this educational model will require continuous feedback and adaptation to emerging technologies and industry standards. Ensuring that the curriculum remains relevant and effective, hence future research should focus on longitudinal studies to assess the long-term impact of these educational reforms on career trajectories and industry advancements, as well as exploring the potential for international collaboration to further enhance the global applicability of this innovative teaching approach.

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