

Research on the Reconstruction of High-quality Navigation Talent Training System Based on the Intelligent Ship Technology Spectrum

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Abstract:

The rapid advancement of next-generation technologies such as artificial intelligence, big data, and the Internet of Things has deeply integrated into the shipping sector, propelling intelligent ships to the forefront of the industry's transformation and modernization. This shift is not only reshaping the competency requirements for maritime professionals but also revolutionizing the global shipping industry, particularly in the wake of the COVID-19 pandemic which has underscored the importance of efficient and resilient maritime operations. This paper aims to construct a high-quality maritime talent cultivation reform model driven by the "Intelligent Ship Technology Spectrum" and framed by the "Four-Dimensional Synergy" framework. First, it systematically analyzes the technological spectrum of intelligent ships in four major domains: "intelligent navigation, intelligent hull, intelligent engine room, and intelligent integrated platform," along with the corresponding three core competency requirements: "multidisciplinary knowledge integration, data-driven decision-making, and innovative systems thinking." Second, it diagnoses prominent issues in current maritime education, such as rigid professional clusters, inadequate resource sharing, superficial industry-education integration, and delayed quality assurance. Building on this foundation, the paper innovatively proposes a "technology-profession-resource-mechanism" four-dimensional synergy framework for restructuring maritime professional clusters. It elaborates on specific implementation pathways, including a modular curriculum system centered on "Maritime Technology+," a smart resource-sharing platform, a cross-domain collaborative education community, and a PDCA cycle quality assurance system. This study aims to offer theoretical underpinnings and actionable strategies for comprehensive reforms in higher vocational education within the maritime sector, drawing upon the innovative frameworks and practical experiences detailed in recent maritime education reform literature., developing a new generation of versatile, innovative, and forward-thinking technical and skilled talents equipped to master and innovate within the realm of future intelligent shipping systems.

Keywords:

Maritime Education, Talent Cultivation, Technological Lineage, Professional Cluster Restructuring, Four-dimensional Linkage, Intelligent Ship

1. Introduction

As the lifeblood of global trade, the shipping industry is experiencing a profound transformation characterized by intelligentization. Smart ships, by integrating sensor technology, communication systems, automated control systems, and artificial intelligence, have realized autonomous, efficient, and eco-friendly navigation, management, and maintenance. This technological convergence not only enhances operational efficiency and safety but also prioritizes energy conservation and emission reduction, aligning with the green shipping trend. The International Maritime Organization (IMO), along with major shipping nations and leading enterprises, has identified smart ships as a pivotal strategic priority, recognizing their potential to revolutionize the maritime industry. This is evidenced by the IMO's decision at the 2017 Maritime Safety Committee meeting to add "regulatory review of Autonomous Surface Ships (ASS)" as a task, as well as the proactive initiatives by countries like Norway, the United States, and the United Kingdom, along with classification societies, in the smart ship sector. This transformation signifies not merely technological progression but a profound restructuring of maritime talent competency frameworks. The conventional single-discipline training paradigm, focused on ship handling skills and electromechanical management, can no longer accommodate the emerging characteristics of ships as "intelligent cyber-physical systems in the ocean."

At present, China's maritime higher education, especially the vocational education that undertakes the main task of cultivating technical and skilled talents, has significant "response lag" and "systematic deficiencies" in responding to this change. Key issues include outdated curricula that do not keep pace with industrial technological advancements; rigid disciplinary boundaries among maritime technology, marine engineering, and ship electronics/electrical engineering, which hinder interdisciplinary competency development; fragmented teaching resources, which limit the adoption of modern tools such as virtual simulation training; superficial school-enterprise collaborations, which result in ineffective collaborative talent cultivation mechanisms; and quality evaluation systems disconnected from new standards and job requirements in intelligent shipping.

Therefore, the central proposition of this study is: How to systematically reconstruct the maritime talent cultivation system to dynamically respond to the evolution of intelligent ship technology ecosystems and sustainably produce high-quality professionals? This paper seeks to transcend the limitations of single-discipline reforms by adopting a meso-system perspective of "professional clusters." The proposed reform framework integrates technology ecosystems as foundational inputs and aims to cultivate high-caliber talent as its primary output, encompassing all critical elements such as disciplines, resources, and mechanisms. This framework aims to leverage the latest advancements in smart ship technology and the transformation of the shipbuilding industry towards smart manufacturing, as evidenced by the innovative training models for maritime professionals in the context of smart ships. provide actionable solutions for the modernization of maritime education.

2. Evolution of Intelligent Ship Technology Spectrum and Fission of Talent Capability Demand

2.1. Core Architecture of Intelligent Ship Technology Spectrum

Intelligent ships are not a single technology but a complex technological ecosystem. This ecosystem can be summarized into four core domains forming an interconnected hierarchical structure: the Core Drive Layer, Technology System Layer, and Value Goal Layer. The Core Drive Layer utilizes data, algorithms, computing power, and high-speed connectivity to establish intelligent fuel and engine systems. The Technology System Layer includes intelligent navigation, hull design, engine room management, and integrated platforms. Intelligent navigation encompasses situational awareness via multi-source data fusion, AI-driven collision avoidance and path optimization, along with remote control and autonomous navigation capabilities, enabling ships to "see, think, and act decisions." The intelligent hull covers structural health monitoring via IoT, stress and corrosion status detection, lightweight materials, and new material applications, with the core focus on ensuring the vessel's safety and performance. The intelligent engine room features predictive maintenance, energy efficiency optimization for main engines and propulsion systems, and unmanned duty systems, emphasizing smart management and health maintenance of the ship's "heart." The Value Goal Layer represents the ultimate goal of all technologies, serving the new paradigm of "safe, efficient, green, and economical" shipping.

2.2. Three-dimensional capability requirement model driven by technology lineage

The evolution of technological lineage has directly led to a tripartite division in the competency requirements for maritime professionals:

(1) Multidisciplinary knowledge integration capability. Professionals must transition from mastering single-discipline knowledge such as "navigation" or "marine engineering" to become proficient in an integrated knowledge system that encompasses "navigation technology + information technology + automatic control + data analysis". For instance, mastering autonomous collision avoidance algorithms entails a deep understanding of maritime regulations such as COLREGs, radar principles, programming logic, and the fundamentals of machine learning, as evidenced by recent research in the field.

(2) Data-driven analysis and intelligent decision-making capabilities. In the face of massive data generated Based on ship sensor data, professionals must be able to perform data cleaning, analysis, and visualization interpretation. They should also be capable of understanding, evaluating, and even participating in the optimization of AI algorithm recommendations, ultimately making safety judgments through human-machine collaboration.

(3) Systematic Thinking and Collaborative Innovation Capabilities. As a complex mega-system, ships require professionals to possess a holistic perspective, capable of Intelligent navigation decisions play a crucial role in optimizing energy consumption within the engine room and mitigating the cascading effects of equipment failures across the ship's systems. Additionally, they must demonstrate the capacity for innovative emergency responses in sudden and complex scenarios.

The three abilities together constitute the "new basic qualities" of navigation talents in the era of intelligent shipping. They are closely connected and mutually supportive,

transcending the scope of traditional skills and advancing to higher levels of cognition and collaboration.

3. Diagnosis of Problems in the Current Higher Vocational Education System for Navigational Talents

Facing the above-mentioned competency requirements, the current maritime vocational education system has exposed the following structural contradictions:

(1) Low Compatibility Between Professional Cluster Structure and Technological Genealogy

Current professional clusters are predominantly organized according to traditional maritime sectors, including navigation, marine engineering, and marine electronics, exhibit limited interdisciplinary integration. Intelligent ship technology, exemplified by the 'Intelligent Integrated Platform,' spans all these domains but lacks corresponding specialized academic disciplines. The misalignment between professional adjustments and technological advancements has led to outdated and limited teaching content.

(2) Rigid Curriculum System and Lack of Resource Sharing Mechanism

The Current curriculum design primarily adheres to disciplinary logic, yet there is a notable absence of modular courses tailored to the specific tasks of intelligent ships, a gap that could be filled by incorporating AI-driven modular design principles. The independent construction of resource repositories by each discipline leads to the creation of 'information silos,' a phenomenon that hinders interdisciplinary collaboration and information sharing. Despite the promotion of virtual simulation teaching applications and the sharing of high-quality resources, such as virtual simulations and big data cases, across disciplines remains challenging, leading to issues of redundant construction.

(3) Insufficient Integration of Industry and Education, Outdated Collaborative Education Model

The collaboration between schools and enterprises remains at a superficial level, primarily confined to student internships and lectures delivered by corporate experts. Enterprises demonstrate insufficient involvement in core teaching processes such as curriculum development, standard setting, and faculty co-education, resulting in a "last-mile" gap between training specifications and actual job requirements. An effective collaborative education mechanism involving schools, enterprises, and research institutions has yet to be established.

(4) The quality assurance system fails to meet competency-based requirements

Current evaluation systems primarily focus on theoretical knowledge examinations and traditional skill assessments, but they fall short in meeting the educational demands of the new era, particularly in evaluating emerging competencies such as data analysis capabilities, systems thinking, and human-machine collaboration. The graduate tracking feedback mechanism is not well-established, failing to establish a sustained improvement cycle grounded in industry talent development data.

4. Reconstructing the Four-Dimensional Linked Talent Training System Based on “Technology-Professional-Resource-Mechanism”

4.1. Four-dimensional linkage reconstruction framework based on “technology-profession-resource-mechanism”

To systematically address the aforementioned issues, this paper proposes a four-dimensional interconnected framework for restructuring maritime vocational education, drawing inspiration from the innovative practices and theoretical frameworks discussed in the references. education clusters. The framework underscores dynamic coupling and co-evolution across its dimensions, particularly:

(1) Dynamic Mapping of Technological Lineages and Demand Transformation

First, establish the ‘Intelligent Ship Technology Development Monitoring Committee’, comprising university and industry experts, to regularly release reports on technological evolution and job competency analysis. The technological spectrum will be broken down into teachable “knowledge modules”, “skill units”, and “competency requirements”, serving as direct inputs for professional and curriculum reforms. Second, develop a “professional construction-technological evolution dynamic coupling model” to enable education content to sensitively respond to and proactively align with technological advancements.

(2) Reconstruction of the “Maritime Technology+” Modular Professional Cluster

The first initiative involves intelligent upgrading of traditional academic clusters. In the Navigation Technology program, modules such as “Big Data Analysis in Navigation” and “Fundamentals of Intelligent Collision Avoidance Algorithms” will be integrated. The Marine Engineering program will improve courses like “Smart Equipment Maintenance” and “Energy Efficiency Management”. Concurrently, new interdisciplinary clusters will be established, replacing traditional administrative classes with specialized tracks like “Navigation Technology + Data Science”, “Marine Engineering + Automatic Control”, and “Shipping Management + Artificial Intelligence”. A modular curriculum system will be implemented, featuring “shared foundational modules, distinct core components, and optional extensions”. Simultaneously, an integrated curriculum framework combining “job competencies, courses, competitions, and certifications” will be developed, Incorporating standards for new intelligent ship roles, the National Vocational College Skills Competition emphasizes the integration of advanced practical skills and professional competencies, as reflected in the detailed competition regulations and technical requirements. “Intelligent Shipping” category, along with emerging vocational skill certifications, into the curriculum.

(3) Development of an Intelligent and Open Resource Sharing Platform

The initiative creates a “Smart Maritime Education Cloud Platform” that combines online open courses, virtual simulation experiments, digital textbooks, real-world case libraries, and industry-leading reports, facilitating cross-disciplinary and cross-institutional on-demand learning. It also develops an “Intelligent Ship Virtual Simulation Training Center” utilizing digital twin technology to create immersive training programs for high-risk, high-cost, and high-difficulty scenarios. Furthermore, it collaborates with leading shipping companies and intelligent ship solution providers to establish “Industry-Education Integration Innovation Practice Bases” on campus or in corporate parks. These platforms integrate practical teaching, technological R&D,

and social services, providing students with access to state-of-the-art technologies and practical projects.

(4) Innovation in Collaborative and Closed-Loop Educational Mechanisms

The initiative commenced with the creation of a “Cross-Domain Collaborative Education Community,” bringing together vocational colleges, applied undergraduate institutions, shipping enterprises, shipbuilding companies, research institutes, and industry associations to establish a fully functional alliance. It introduced a “dual-mentor system” integrating “industry mentors” and “academic mentors” to jointly guide graduation projects and innovation initiatives. Simultaneously, the “PDCA cycle” quality improvement mechanism was implemented to ensure continuous enhancement.

4.2. Key Pathways for Implementing the Restructuring of Talent Cultivation System

(1) Path of Curriculum System Reconstruction

Following the systematic logic of “analyzing the technical spectrum - deconstructing job tasks - summarizing ability elements - designing course modules”, the original course system is structurally optimized and content reorganized, with a focus on developing three major modules: “Professional Basic Course Group”, “Intelligent Technology Core Course Group”, and “Cross Extension Course Group”, forming a hierarchical and ability oriented course architecture. During implementation, the significant rise in the adoption of project-based and case-based courses has led to a deeper integration of theoretical instruction with practical application, as evidenced by the growing emphasis on student-centered learning environments. practical application aimed at enhancing students’ engineering practice and innovation capabilities.

(2) Strategies for Co-constructing Teaching Resources

Through a collaborative framework featuring “university-enterprise co-development, shared intellectual property rights, and continuous iteration updates,” we systematically advance the development and integration of teaching resources. We actively encourage faculty to transform cutting-edge research into high-quality teaching cases, while guiding enterprises incorporate real-world engineering challenges into classrooms as practical training projects. Additionally, we establish a scientifically validated resource certification system and a points-based incentive mechanism to fully engage teachers, enterprises, and students, thereby fostering a sustainable ecosystem for resource renewal.

(3) Transformation and Development of Faculty

The system implements the “Teacher Competency Enhancement Program” through multiple approaches: assigning teachers to corporate internships by organizing high-level specialized training both domestically and internationally, and supporting their active involvement in technology R&D and commercialization projects. These initiatives aim to transform traditional maritime education instructors into “dual-qualified, triple-skilled” professionals who excel in both pedagogy and engineering, possessing integrated capabilities in teaching, practical engineering, and technological innovation. Concurrently, the program intensifies recruitment of high-caliber talents who possess deep industry expertise and practical experience in intelligent technologies, thereby optimizing the faculty structure.

(4) Innovation Direction of Evaluation System

We are driving a fundamental shift in evaluation philosophy from traditional “knowledge assessment” to “competency certification”, while actively exploring diversified, process-oriented, and comprehensive evaluation methods. The implementation of electronic portfolio systems comprehensively documents students' performance and outcomes in project-based practices and innovation activities. Leveraging virtual simulation technologies, we create realistic complex scenarios to systematically assess students' decision-making capabilities and systems thinking proficiency. Furthermore, corporate evaluations, academic competition achievements, and innovation/entrepreneurship practices are integrated into the credit recognition system, establishing a more scientific and holistic educational framework for student competency assessment.

5. Conclusion and Prospects

The rapid advancement of intelligent ship technology, which enhances safety, efficiency, and environmental friendliness, necessitates a systematic restructuring of maritime talent cultivation systems. This study proposes a “four-dimensional linkage” framework based on the technological spectrum of intelligent ships, aiming to break the path dependence of traditional education and establish a new talent production model that can agilely respond to industrial changes, deeply integrate resources and continuously self-optimize. Its core value lies in transforming exogenous technological variables into internal driving forces for educational reform. Through the coordinated design of professional expertise, resources, and mechanisms, it ensures the effective cultivation, evaluation, and safeguarding of new competency requirements.

Future research and practice should focus on three key areas. First, develop more detailed, differentiated reform plans for cultivating maritime talents at different levels and types. Second, strengthening research on the ethical and legal aspects of human-machine collaboration, and the psychological and social adjustment resulting from crew role transformation. Third, advancing large-scale validation of the framework while continuously refining evaluation scales and dynamic adjustment models. Only through these efforts can maritime education truly support China's grand strategy of transitioning from a shipping powerhouse to a smart shipping leader, laying a solid talent foundation for building a maritime power.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this article.

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References

- [1] International Maritime Organization (IMO). Outcome of the regulatory scoping exercise for the use of maritime autonomous surface ships (MASS). MSC.1/Circ.1638, 2021.
- [2] Ministry of Transport, et al. Guidelines for the Development of Intelligent Shipping. Jiaoshuifa, 2019.
- [3] Clarksons Research. Shipping Intelligence Weekly. Issue 1034, January 2024.
- [4] Wang Renqiang, Zhang Jiting. “Research on the Restructuring of Navigation Vocational Specialties Clusters under the Background of Intelligent Ship Technology Evolution” Project Application Form. Jiangsu Provincial Higher Education Teaching Reform Research Project, 2024.
- [5] DNV. Maritime Forecast to 2050: Energy Transition Outlook 2023. Høvik: DNV AS, 2023.
- [6] Zhao, J.S.; Wang, S.Z.; Liu, Y.H. Development trends of intelligent ships and new requirements for crew qualifications. *Maritime Education Research*, 2021, 38(3), 1-7.
- [7] International Chamber of Shipping (ICS). Seafarer of the Future: Skills Needs Analysis. London: ICS, 2022.
- [8] Ma, S. On the Paradigm Shift of Intelligent Revolution and Nautical Education. *China Navigation*, 2020, 4, 105-110.
- [9] European Maritime Safety Agency (EMSA). Annual Overview of Marine Casualties and Incidents 2022. Lisbon: EMSA, 2023.
- [10] UNESCO International Centre for Vocational and Technical Education and Training (UNESCO-UNEVOC). Vocational and Technical Education and Training in the Digital Economy: Global Trends and Case Studies. Bonn: UNESCO-UNEVOC, 2022.
- [11] Maritime Safety Administration of the People’s Republic of China. Implementation Measures of the Regulations on the Examination and Certification of Seafarers of the People's Republic of China. 2020.
- [12] World Maritime University (WMU). Transport 2040: Automation, Technology, Employment - The Future of Work. Malmö: WMU, 2019.
- [13] Sun, Y.Q.; Li, B.; Liu, J.L. Research on the Construction of an Intelligent Ship Experimental Teaching Platform Based on Digital Twin. *Laboratory Research and Exploration*, 2022, 41(8), 231-235.
- [14] The Royal Institution of Naval Architects (RINA). Autonomous Ships: The Next Step. London: RINA, 2021.



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