

Research on Digital Transformation Scheme Design for Maritime Vocational Education

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Abstract:

As the global shipping industry accelerates its transition toward intelligentization and green development, traditional maritime vocational education faces structural challenges including limited practical training environments, monotonous teaching models, and insufficient lifelong education coverage. Grounded in vocational education informatization theory and industry-education integration theory, this study systematically analyzes the practical drivers and core challenges of digital transformation in maritime vocational education, proposing an integrated digital transformation framework featuring “professional leadership, technological empowerment, industry-education collaboration, and lifelong education coverage.” The solution focuses on four dimensions: digital restructuring of professional clusters, intelligent upgrading of teaching scenarios, ecological construction of industry-education integration, and systematic advancement of digital governance systems, aiming to cultivate versatile high-quality technical professionals adaptable to the intelligent shipping era. The research concludes that digital transformation is not merely a simple combination of technology and education, but a systematic reshaping of vocational education concepts, models, and operational frameworks, requiring a tripartite safeguard mechanism encompassing organizational structure, financial support, and safety protocols. This framework provides theoretical references and practical insights for digital transformation initiatives in similar vocational institutions.

Keywords:

Maritime Vocational Education, Digital Transformation, Industry-education Integration, Virtual Simulation, Lifelong Learning

1. Introduction

Since the 21st century, digital technologies have been reshaping the global industrial landscape at an unprecedented pace. As the lifeline of international trade, the shipping industry is undergoing a profound transformation from “experience-driven” to “data-driven” operations. The widespread adoption of cutting-edge technologies - including autonomous ship navigation systems, intelligent shipping management platforms, and maritime big data analytics - has created new demands for maritime professionals’ digital literacy, interdisciplinary competencies, and

innovative thinking. The International Maritime Organization (IMO) explicitly states in its Temporary Guidelines for Autonomous Surface Ships (MASS) that future maritime talent must possess both traditional navigation skills and digital operational capabilities [1].

The digital transformation of maritime vocational education abroad began relatively early. Shipping powerhouses like Norway and the Netherlands have established nationwide maritime virtual training networks, extensively applying AR/VR technologies in core skill training such as ship handling and engine room maintenance. The International Maritime Universities Association promotes collaborative development of digital course resource libraries among member institutions to achieve cross-border credit recognition [2]. The U.S. Maritime Institute has introduced adaptive learning systems that deliver personalized learning paths based on student behavioral data. Meanwhile, China is accelerating its strategies to build a strong transportation and maritime nation. The National Vocational Education Reform Implementation Plan explicitly outlines the reform direction of “aligning vocational education with industrial demands and keeping pace with technological advancements [3].” In 2023, the Ministry of Education issued the Notice on Key Tasks for Accelerating Modern Vocational Education System Reform, identifying digital transformation as a critical driver for high-quality vocational education development. Against this backdrop, maritime vocational education — as the primary arena for cultivating shipping professionals — urgently requires digital transformation to achieve self-renewal. Domestic research has shown rapid growth in recent years, with scholars conducting explorations on topics such as maritime virtual simulation training platform development, digital course resource creation, and smart classroom construction. Institutions like Jiangsu Maritime Vocational and Technical College and Qingdao Ocean Crew Vocational College have accumulated extensive experience in digital teaching reforms [4]. However, existing studies predominantly focus on single-phase technological applications, lacking systematic frameworks for digital transformation in maritime vocational education.

However, traditional maritime vocational education has exposed multiple structural contradictions in addressing industrial transformation [5]. Firstly, limited practical training environments. Maritime education heavily relies on ship-based training, yet constrained by high operational costs, narrow training windows, and challenges in simulating high-risk scenarios, students suffer from severe lack of hands-on practice. Secondly, monotonous teaching models. Traditional classroom instruction fails to meet personalized learning needs or keep pace with cutting-edge shipping technologies. Thirdly, inadequate lifelong education coverage. The maritime profession's high mobility and limited onshore learning opportunities make existing systems unable to support continuous skill updates throughout careers. Fourthly, insufficient industry-education integration. Information asymmetry persists between academic curricula and corporate demands, resulting in talent development that remains disconnected from job requirements.

This study aims to develop a systematic digital transformation framework for maritime vocational education, which holds significant theoretical and practical value in addressing the aforementioned challenges. Theoretically, it integrates vocational education informatization theories and industry-education integration frameworks into maritime education, exploring the underlying mechanisms of deep digital technology integration. Practically, through systematic design and implementation pathway planning, the proposed solution can provide actionable and replicable transformation

models for maritime vocational institutions, thereby supporting the cultivation of industry-ready talent for the intelligent shipping sector.

2. Theoretical Basis

2.1. Theoretical Connotation of Digital Transformation in Vocational Education

Digital transformation differs fundamentally from simple information infrastructure development. Its essence lies in leveraging digital technologies to systematically reshape organizational processes, value creation models, and corporate culture. For vocational education, this transformation encompasses three dimensions: the technological layer (infrastructure and platform development), the competency layer (enhancing digital literacy among educators and students), and the ecosystem layer (industry-education collaboration and governance model innovation). Scholars like Zhu Zhiteng [6] emphasize that vocational education's digital transformation should evolve from "technological empowerment" to "value redefinition," achieving comprehensive digital restructuring across all educational elements, processes, and domains.

2.2. New Developments in Industry-Education Integration Theory

Industry-education integration serves as the fundamental operational model for vocational education. With the rise of the digital economy, its conceptual scope continues to expand. The traditional "school-enterprise collaboration" is evolving into an "industry-education integration ecosystem," emphasizing the organic alignment of industrial chains, educational systems, talent pipelines, and innovation networks. In the digital era, this integration demonstrates new characteristics of platformization, collaborative synergy, and intelligent automation. Enterprises now participate deeply throughout the talent development process--not only as demand-side entities for skilled labor but also as providers of educational resources and partners in technological R&D.

3. Realistic Driving Forces for Digital Transformation in Maritime Vocational Education

3.1. Industry Demand Driven: Intelligent Shipping Forces Restructuring of Talent Competency Framework

The era of intelligent shipping has brought profound transformations to the competency structure of maritime professionals. Traditionally, core competencies in navigation focused on practical skills like ship handling, navigation safety, and cargo stowage. Today, emerging requirements include data acquisition and analysis capabilities, intelligent equipment operation and maintenance skills, as well as emergency decision-making and risk assessment abilities. For instance, the operation of smart ships relies on real-time analysis of massive sensor data, demanding basic data literacy from maritime personnel. Fault management in automated navigation systems requires professionals to understand system logic rather than relying solely on experiential judgment.

This transformation in competency structure implies that vocational education must shift from a "skills training" orientation to a comprehensive cultivation model encompassing "technical literacy + professional skills + innovative thinking." The

traditional teaching model, which primarily relies on lectures with supplementary practical training, struggles to support the development of interdisciplinary competencies.

3.2. Educational Dilemmas: Systematic Limitations of Traditional Models

The maritime vocational education sector has long grappled with three persistent challenges: sustaining high investment, replicating high-risk scenarios, and ensuring coverage for high turnover rates. Take ship training as an example: the annual operational costs of a training vessel can reach tens of millions of yuan, while training windows are constrained by weather conditions and shipping routes. High-risk scenarios like ship collisions and grounding cannot be simulated in real environments, leaving students without emergency response training. Additionally, seafarers' year-round maritime voyages make systematic continuing education difficult to implement.

Furthermore, the traditional teaching model exhibits a contradiction between "standardization" and "personalization [7]." Uniform teaching schedules struggle to accommodate diverse learning paces among students, while standardized instructional content fails to meet the varied career development needs. Digital transformation provides technical solutions to address these contradictions.

3.3. Superimposed Policy Opportunities: Synergistic Resonance Between National Strategy and Educational Reform

In recent years, China has rolled out a series of national policies to drive digital transformation in vocational education. In 2022, the Ministry of Education launched the "Digital Strategy Action for Vocational Education," outlining key initiatives including building smart education platforms, upgrading professional teaching resource databases, and fostering digital benchmark institutions. The Ministry of Transport's "Guidelines on Promoting High-Quality Development of the Maritime Industry" emphasized "strengthening maritime talent cultivation and innovating educational models [8]." These policy incentives have provided robust support for the digital transformation of maritime vocational education.

4. Digital Transformation Plan Design for Maritime Vocational Education

4.1. Design Philosophy and Objectives of the Scheme

This program focuses on cultivating versatile, high-caliber technical professionals adaptable to the intelligent shipping era, guided by the design philosophy of "professional leadership, technological empowerment, industry - education collaboration, and lifelong learning coverage." Professional leadership emphasizes restructuring academic programs based on industry demands; technological empowerment highlights the deep integration of digital technologies throughout the teaching process; industry-education collaboration underscores the deep integration of talent co-development, resource sharing, and joint technological research between schools and enterprises; lifelong learning coverage emphasizes establishing a comprehensive learning support system spanning seafarers' entire career trajectories.

The program is committed to achieving three key transformation objectives: enhancing talent cultivation quality to ensure over 95% graduate job fit rate; improving teaching efficiency and satisfaction by increasing faculty lesson

preparation efficiency by 30% and achieving course satisfaction rates above 95%; and strengthening social service capabilities through annual virtual simulation training center training exceeding 20,000 participants and overseas access to teaching resource libraries surpassing 200,000 visits.

4.2. Digital Restructuring of Professional Clusters

(1) Dynamic professional adjustment mechanism adapted to industrial demands

A professional development committee composed of university faculty, shipping industry technical experts, and industry association representatives has been established to implement a closed-loop mechanism of “research - evaluation - adjustment - feedback.” Annual industry competency surveys are conducted to track advancements in intelligent shipping technologies and optimize program offerings accordingly. Priority is given to developing interdisciplinary programs such as Intelligent Navigation Technology, Green Ship Engineering, and Smart Shipping Management, forming specialized clusters through industry-academia integration. Taking the Intelligent Navigation Technology program as an example, its curriculum covers core subjects including Intelligent Ship System Principles, Maritime Big Data Analysis, and Ship Cybersecurity Management, ensuring precise alignment between academic programs and the intelligent shipping industry chain.

(2) A digitally restructured curriculum system with end-to-end chain integration

With digital literacy as the core, the course content is being restructured. Key courses now include ship intelligent system operations, maritime big data analysis, and virtual simulation emergency response, with the development of a distinctive “AI + Navigation” course module. Leveraging domestic large-scale models, a professional knowledge graph is constructed to enable dynamic updates and personalized content delivery. Specifically, the knowledge graph links knowledge points, skill points, and job competency requirements, automatically triggering course content update reminders based on industry technological changes, which are then reviewed and incorporated into teaching by instructors. Meanwhile, aligning with international maritime education standards, the curriculum system is being harmonized with global practices. The International Maritime Organization Model Courses (IMO Model Courses) are introduced and localized through China’s maritime practices, achieving international alignment in course content, assessment standards, and credit recognition.

4.3. Intelligent Upgrade of Teaching Scenarios

(1) Construction of a Training System Integrating Virtual and Real Elements

The project involves establishing a national-level virtual simulation training center for maritime disciplines, developing a high-fidelity virtual training system covering core scenarios such as ship handling, engine room maintenance, and maritime emergency response. The system integrates physics engines with real-world data to simulate high-risk scenarios including complex sea conditions, sudden malfunctions, and emergency events, while supporting multi-person collaborative training. Equipped with an intelligent evaluation module, it continuously records operational trajectories, analyzes operational compliance, and generates personalized diagnostic reports.

The integrated virtual-physical training platform seamlessly combines virtual simulation with physical equipment. Students first undergo cognitive training and

operational practice in a virtual environment. After mastering basic procedures, they transition to semi-physical simulation devices, ultimately completing comprehensive assessments on physical equipment. This progressive training model - progressing from virtual simulation to semi-physical systems and finally to physical equipment - ensures training safety while significantly enhancing practical skill development outcomes.

(2) Implementation of Personalized Intelligent Teaching

The AI-powered intelligent teaching assistant system is introduced to achieve precise content delivery and personalized learning path planning based on student learning data profiles. By analyzing operational records during virtual training sessions, online course viewing behaviors, and homework completion status, the system identifies learning difficulties and knowledge gaps, then automatically recommends differentiated learning resources.

Leveraging AIGC technology, educators can rapidly generate teaching resources such as micro-lecture videos and interactive courseware, significantly enhancing lesson preparation efficiency. A dual-track guidance model combining “digital teaching assistants + in-person instructors” has been implemented: AI assistants handle knowledge point explanations, assignment grading, and Q&A sessions, while teachers focus on personalized tutoring, cognitive guidance, and practical instruction. This division of labor liberates teachers from repetitive tasks, allowing them to return to their core mission of nurturing students.

(3) Establishment of a lifelong learning cloud platform

In response to the high mobility of seafarers and their urgent need for lifelong education, a maritime lifelong learning cloud platform has been established. The platform integrates national-level teaching resource libraries for specialized disciplines such as marine engineering technology, develops modular micro-courses, and supports fragmented learning. Seafarers can access the latest technical courses via mobile devices during navigation breaks and complete online assessments.

Establish a learning outcome certification system to achieve credit recognition between vocational training and academic education. Outcomes obtained by seafarers through corporate training, online learning, and skills competitions can be credited to academic education after certification, thereby constructing a lifelong learning closed loop of “academic education - vocational training - skill enhancement”.

4.4. Construction of Industry-Education Collaborative Ecosystem

(1) Construction of an Industry-Education Integrated AI R&D Center

In collaboration with enterprises such as Jinzhi Education and Haoxun Technology, as well as the Jiangsu Artificial Intelligence Society, a Industry-Education Integrated AI Agent R&D Center was jointly established. The center focuses on the digitalization needs of maritime education, jointly developing intelligent teaching tools, virtual training systems, knowledge graphs, and other products. A joint R&D team composed of corporate technical personnel and academic faculty promotes the teaching transformation of technological achievements.

Based on real enterprise projects, the “On-site Engineer Training Program” is implemented. Students participate in R&D center operations as project assistants, enhancing their technical application capabilities and engineering mindset through

practical projects. The R&D center also serves as a platform for faculty practical training, regularly arranging faculty participation in corporate technological breakthroughs to maintain sensitivity to industry frontiers.

(2) Deepening of Multi-dimensional Collaborative Education Model

The company has strengthened collaboration with industry leaders such as Zhongquan Group and Xiamen Panhai, establishing customized order-based training programs and on-site engineer training courses. Through full participation in talent development planning, curriculum design, practical training guidance, and performance evaluation, the initiative achieves seamless alignment between talent cultivation and job market demands. Students enrolled in these order-based programs begin their careers immediately upon enrollment, with enterprises providing scholarships and internship opportunities, ensuring graduates can directly transition into corporate employment upon graduation.

Introduce industry-standard skills competition benchmarks to enhance teaching and learning through competitive engagement. Integrate the content and criteria of WorldSkills Competitions and National Vocational College Skills Competitions into daily instruction, encouraging students to participate in competitions at various levels to improve professional skills and innovative capabilities. The competitive training process itself serves as a crucial pathway for cultivating high-quality technical and skilled talent.

4.5. Systematic Upgrade of Digital Governance

(1) Construction of Smart Campus Management Platform

Establish a “1+3+N” smart campus information service system, comprising one smart campus platform, three foundational pillars of collaboration, data, and AI applications, which covers multiple business systems across teaching, management, and service domains. The smart campus platform facilitates data integration and operational synergy among various business systems, eliminating information silos.

Data analysis applications are pivotal to achieving smart governance. Through teaching data analysis, dynamic monitoring and precise evaluation of teaching quality can be realized. For instance, the system can track real-time metrics such as course progress, practical training duration, and teacher-student interaction frequency, automatically generating improvement suggestions for warning indicators to facilitate the transition from “experience-driven” to “data-driven” management practices.

(2) Enhancement of Teachers’ Digital Teaching Competence

Regular specialized training sessions on AI technology applications are conducted, inviting university experts, scholars, and corporate technical engineers to deliver lectures. The training content covers AI-powered curriculum development, large model applications, and intelligent office tool usage, aiming to enhance teachers’ digital teaching literacy and technical application capabilities.

Establish a special project on artificial intelligence-enabled teaching reform to encourage teachers to engage in innovative teaching practices. Annually select and promote a batch of exemplary teaching cases to create a demonstrative effect. Develop a digital competency certification system for teachers, incorporating digital teaching capabilities into teacher performance evaluation indicators.

5. Conclusions

This study systematically analyzes the practical drivers of digital transformation in maritime vocational education and proposes an integrated digital transformation framework featuring “professional leadership, technological empowerment, industry-education collaboration, and lifelong coverage.” The research demonstrates that digital transformation transcends mere technological integration with educational systems, representing a systemic reshaping of maritime vocational education's core concepts, operational models, and institutional structures. Four pivotal pillars underpin this transformation: digital restructuring of professional clusters, intelligent upgrading of teaching environments, establishment of industry-education collaborative ecosystems, and systematic advancement of digital governance mechanisms. These elements collectively form a robust framework for cultivating a new maritime education ecosystem tailored to the intelligent shipping era.

Digital transformation is a profound educational revolution that requires strategic resolve and sustained investment. Only by adhering to the principles of putting people first, applying technology, and basing education on industry can we forge a digital transformation path for maritime vocational education with China's characteristics, providing solid talent support for the strategies of building a strong transportation nation and a strong maritime nation.

Conflicts of Interest

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

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