Research on the Construction of an AI-Based Virtual Collaborative Practice Platform for Sino-Foreign Cooperative Shipbuilding

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Abstract: To address key challenges in practical teaching of naval architecture and ocean engineering in Sino-foreign cooperative education—insufficient experimental conditions, high real-ship experiment costs/risk, and disjointed teaching-industry technologies—this paper proposes an AI-based virtual collaborative practice platform. Integrating virtual simulation, AI real-time cross-lingual translation, VR/AR interaction and personalized learning recommendation, it builds a 1:1 virtual shipyard to reproduce the whole shipbuilding process, with a tiered experimental system and cross-border collaborative teaching model. the platform breaks temporal/linguistic barriers, reduces teaching costs and risks, aligns teaching with industry frontiers, providing a solution for cultivating high-quality interdisciplinary talents with international perspective and engineering capabilities, and serving as a reference for digital transformation of similar programs.

Keywords: Artificial Intelligence; Virtual Simulation; Sino-Foreign Cooperative Education; Shipbuilding; Practical Teaching

1. Introduction

1.1 Research Background and Problem Statement

As the global shipbuilding industry rapidly accelerates toward intelligence, greenization and digitalization, Sino-foreign cooperative education has become a vital pathway for cultivating interdisciplinary talents with an international vision, mastery of international standards, and local practical expertise. the Naval Architecture and Ocean Engineering program at Jiangsu Ocean University was designated a national first-class undergraduate program in 2020, and the Makarov College of Marine Engineering was founded in 2021. In the first half of 2024, Jiangsu Province accounted for over 40% of China's shipbuilding completion and new orders, and more than 25% of the global total, having ranked first in China for 15 consecutive years. This development has created an urgent demand for high-quality international talents.

However, shipbuilding is a highly practice-oriented discipline, with its teaching facing three core challenges. First, insufficient experimental conditions fail to meet the demands of conventional teaching, let alone those of Sino-foreign cooperation, such as aligning with international standards, integrating foreign cases, and enabling cross-border collaboration. Second, real-ship experiments are prohibitively expensive and risky, involving substantial investment and hazards like equipment collapse and injury, which severely restricts practical teaching. Third, outdated technologies and rigid models slow the incorporation of cutting-edge advances like AI and digital twins, lacking interactivity and engagement. In this context, building an AI-enabled virtual collaborative practice platform is crucial for overcoming these hurdles and innovating the cultivation of internationally oriented applied talents.

1.2 Research Purpose and Significance

This study aims to keep up with the international development trends of the shipbuilding industry and the requirements of educational informatization and intelligence. By using artificial intelligence technologies, it intends to overcome the limitations of traditional shipbuilding practice teaching, construct a virtual collaborative practice platform for Sino-foreign cooperative shipbuilding, integrate high-quality Chinese and foreign educational resources, and innovate a cross-border collaborative teaching model to provide an efficient solution for shipbuilding talent cultivation. Specifically, it aims to build an AI-integrated virtual simulation platform with a realistic virtual shipyard, AI translation and VR/AR modules, and a shared teaching resource pool, as well as innovate a virtual collaborative teaching model with tiered tasks, personalized content and AI-based teaching feedback to enhance international talent quality.

This paper is divided into nine sections: the first elaborates on the research background and significance, the second reviews domestic and foreign research status, the third presents the theoretical foundation and overall design framework, the fourth introduces key technology implementation, the fifth analyzes teaching practice and expected outcomes, and the last draws conclusions.

2. Current State of Research in China and Abroad

2.1 Development of Shipbuilding Virtual Simulation Technology

Shipbuilding virtual simulation technology uses 3D digital models and computer graphics to create realistic virtual ship production environments, helping operators master processes, improve capabilities and shorten construction cycles [1]. With the development of computer technology, it has become an independent discipline and a key way to understand shipbuilding processes, and has been gradually applied in shipbuilding and university teaching through domestic and foreign cooperation between institutions, universities and enterprises.

Internationally, the US took the lead in applying this technology in shipbuilding in 1992. Markus Koenig et al. from the University of Michigan developed immersive virtual technology to solve ship construction errors [2]; Okumoto (Korea) and Hiyoku (Japan) built a 3D digital shipyard to replicate shipbuilding processes [3]; Norway's Ulstein Design used it to evaluate drilling vessels and simulate their construction and operation [4]. In China, the application started late but developed rapidly. Xie Lei et al. from Shanghai Jiao Tong University established a shipbuilding simulation process and evaluation indicators [5]; Liu Xuegeng studied its application in shipyard pipe production logistics [6]; Shao Ziming et al. from Jiangsu University of Science and Technology developed a ship block simulation system [7], and Wang Yue et al. simulated plane block production to optimize bottlenecks [8]; Zhou Bo from Zhejiang University optimized block assembly processes with simulation software and genetic algorithms [9]. Notably, most Chinese enterprises have not fully tapped the technology's potential, failing to meet the needs of digital and agile shipbuilding.

2.2 Application of AI and Virtual Simulation in Experimental Teaching

For the construction of AI-based virtual collaborative practice platforms in shipbuilding, international research has yielded initial results. Stanivuk et al. from the UK's Royal Naval College applied AI to shipbuilding teaching, broadening students' horizons [10]. Cui-Chao et al. from Korea Maritime and Ocean University used AI simulation for engineering training, significantly enhancing efficiency through 3D modeling [11].

Domestic vocational colleges have also explored AI virtual simulation teaching. Qiao Shuai of Weihai Vocational College built a virtual shipyard via VR technology, simulating the entire shipbuilding process and improving teaching models and student motivation [12]. Sun Chengcheng of Bohai Shipbuilding Vocational College integrated AI virtual simulation into shipbuilding courses, analyzing teaching status and advantages, and exploring practical pathways under the emerging engineering education framework [13].

In summary, AI virtual simulation technology in shipbuilding is mainly applied to production and scientific research. Its use in experimental teaching is limited to vocational colleges. Given the distinct training differences between undergraduate and vocational education, especially as Jiangsu Ocean University aims to cultivate students' practical application capabilities as an applied undergraduate university, conducting research on constructing an AI-based Sino-foreign cooperative virtual collaborative practice platform for shipbuilding holds practical significance. It can provide a model for addressing teaching reform challenges, innovating international talent cultivation models, and promoting high-quality educational development at the university.

3. Theoretical Foundation and Design Framework for Platform Construction

3.1 Theoretical Foundation for Platform Construction

The construction of this platform is grounded in constructivist learning theory, situated learning theory, and cross-border collaborative teaching theory. Constructivist learning theory emphasizes that learning is a process in which learners actively construct knowledge through interaction with their environment. This platform utilizes virtual simulation technology to construct a highly realistic virtual shipyard environment, enabling students to actively explore the principles of shipbuilding through immersive experiences. Situated learning theory posits that learning is embedded in the practical processes of specific contexts. By reproducing the entire shipbuilding process at a 1:1 scale, this platform embeds knowledge within authentic engineering tasks. Cross-border collaborative teaching theory emphasizes that learners from different cultural backgrounds complete learning tasks together through collaboration. the platform’s AI-powered real-time translation module breaks down language barriers and supports the formation of cross-cultural practice groups comprising both Chinese and international students.

3.2 Overall Platform Architecture Design

As shown in Figure 1, the overall architecture of this platform adopts a layered design approach, comprising five layers from bottom to top: the infrastructure layer, data resource layer, technical support layer, business application layer, and user interaction layer. the infrastructure layer provides hardware resources and foundational software resources. the data resource layer includes a three-dimensional model library for shipbuilding, an experimental task library, a teaching resource library, and a database of student learning behaviors. the technical support layer encompasses a virtual simulation engine, an AI translation engine, a VR/AR rendering engine, and a data mining and analysis engine. the business application layer includes a virtual shipyard module, a cross-language collaboration module, a VR/AR experiment module, and a personalized learning module. the user interaction layer provides access points such as a web portal, VR headset interface, and mobile platform.

3.3 Division of Core Functional Modules

The platform comprises five core functional modules. First, the AI-driven real-time terminology translation module constructs a bilingual corpus of shipbuilding terminology and integrates a real-time translation engine. Second, the basic composition cognition module for block construction helps students master the classification logic of hull blocks through interactive courseware. Third, the VR/AR immersive block construction module for large container ships covers the entire process from sub-assembly joining to block assembly. Fourth, the knowledge assessment module includes staged assessments and comprehensive tests. Fifth, the personalized learning recommendation system leverages big data analytics and artificial intelligence algorithms to tailor exclusive learning pathways for each student.

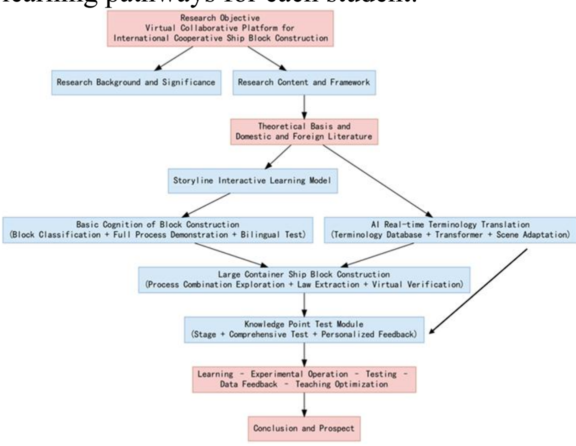

Figure 1. Research Framework for the Construction of an AI-Based Virtual Collaborative Practice Platform for Sino-Foreign Cooperative Shipbuilding

4. Key Technologies for Platform Implementation

4.1 Construction of a High-Fidelity Virtual Shipyard Based on Unity 3D

The platform employs the Unity 3D engine to construct a 1:1 high-fidelity virtual shipyard scene, accurately reproducing the entire experimental process, including hull block assembly, welding, and outfitting. In the model construction process, a layered modeling strategy is adopted: the base layer constructs the overall shipyard environment and equipment models, the process layer constructs detailed operation models for each procedure, and the interaction layer constructs user operation response models. Through the coordination of these three layers, high-precision restoration and smooth interaction of the virtual experimental scene are achieved, with model accuracy reaching the millimeter level.

Figure 2. Deep Integration Using Storyline to Build an Interactive Virtual Collaborative Practice Platform

4.2 AI-Driven Real-Time Terminology Translation Module

Figure 3. Development of an AI-Driven Real-Time Terminology Translation Module

This module leverages natural language processing technology to build a dedicated AI translation system for the shipbuilding domain. the implementation specifically includes: constructing a bilingual corpus of shipbuilding terminology, compiling over 5, 000 Chinese-English terms covering core areas; integrating a real-time translation engine optimized with a Transformer architecture to achieve millisecond-level response; and adapting to virtual collaborative scenarios by embedding the translation module into the platform interface, supporting bidirectional translation of both voice and text, thereby providing solid support for cross-language collaboration between Chinese and international faculty and students.

4.3 VR/AR Immersive Interaction Technology

The platform integrates VR/AR technologies to provide multi-level immersive learning experiences. In VR mode, students enter the virtual shipyard through head-mounted display devices, with spatial positioning technology tracking user movements and achieving a frame rate of over 90 fps. In AR mode, virtual components can be overlaid onto physical models, enabling assembly exercises that integrate virtual and physical elements. the platform offers multiple interaction methods, including controller-based interaction, gesture recognition, and voice control, enhancing immersion and operational realism.

Figure 4. Setting Up the Large Container Ship Block Construction Process

4.4 Personalized Learning Recommendation Algorithm

The platform constructs a personalized learning recommendation system that captures multi-dimensional student information in real time. In terms of user profiling, a multi-dimensional user profile is built based on student learning behavior data. Regarding recommendation algorithm design, a strategy combining collaborative filtering and content-based recommendation is adopted. For the dynamic adjustment mechanism, the system dynamically adjusts the recommendation strategy according to students' real-time learning data, thereby achieving personalized optimization of learning pathways.

Figure 5. Personalized Learning Recommendation Algorithm

4.5 Data-Driven Teaching Evaluation Mechanism

The platform establishes a data-driven teaching evaluation mechanism. In terms of data collection dimensions, it captures operation data, performance data, interaction data, and test data. Regarding intelligent analysis models, it constructs a mastery model, proficiency model, collaboration model, and progress model based on machine learning algorithms. For visual feedback, it provides teachers with a class-level analysis report and students with individual learning reports.

Figure 6. Data-Driven Teaching Evaluation Mechanism

5. Teaching Practice and Promotion Value

This study focuses on practical teaching challenges in the Sino-foreign cooperative Naval Architecture and Ocean Engineering program at Jiangsu Ocean University. By building an "AI+virtual simulation" shipbuilding virtual collaborative practice platform, it solves core issues such as insufficient experimental conditions, high real-ship experiment costs and risks, outdated teaching technologies and monotonous models, innovating cross-border teaching and aligning teaching with industry demands, which is crucial for improving international interdisciplinary talent quality and promoting digital transformation of Sino-foreign cooperative engineering education.

The platform compensates for inadequate experimental facilities via 1:1 virtual simulation of the entire shipbuilding process. Its AI-powered real-time cross-language collaboration and resource integration break cross-border education barriers, enabling immersive joint practice for Chinese and foreign faculty and students. the risk-free environment addresses real-ship experiment challenges, while tiered tasks and personalized recommendations enhance students' international perspectives and practical capabilities. Leveraging Jiangsu's leading shipbuilding industry status, it collaborates with enterprises to integrate latest industry standards into virtual content, and uses platform data to cultivate talents meeting enterprise needs, providing talent support for Jiangsu's shipbuilding industry and a pathway for industry-education integration in Sino-foreign cooperation.

6. Conclusion

This paper addresses core practical teaching challenges in the Sino-foreign cooperative Naval Architecture and Ocean Engineering program, proposing a solution to construct an AI-based virtual collaborative shipbuilding practice platform. Integrating virtual simulation, AI real-time cross-language translation, VR/AR immersive interaction and personalized learning recommendations, the platform innovatively designs a tiered experimental system and cross-border collaborative teaching model, aligning teaching with industry frontiers.

To solve high real-ship experiment costs, risks and low cross-border collaboration efficiency, the research designs a systematic virtual collaborative experimental system. It develops three tiers of virtual experimental tasks (fundamental, comprehensive, innovative) covering the full shipbuilding process, and establishes a "operation-warning-feedback" closed-loop safety control mechanism with AI behavior recognition and hazard scenario simulation. Additionally, it formulates cross-border collaboration guidelines to ensure orderly practical teaching.

Based on Jiangsu Ocean University's positioning as a first-class applied undergraduate institution, this paper focuses on Naval Architecture and Ocean Engineering talent cultivation needs, aligning with shipbuilding industry trends and educational informatization requirements. By using AI to overcome traditional teaching limitations and building the first Sino-foreign cooperative virtual collaborative platform, it integrates Chinese and foreign resources, innovates cross-border teaching, provides an efficient shipbuilding talent cultivation solution, enhances students' comprehensive capabilities, and contributes to cultivating interdisciplinary applied talents meeting industry demands.

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