Article

Exploration of AIGC-Assisted Course Development for Ship Structure and Freight Integration in the Context of Industry-Education Integration

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Abstract: In contemporary maritime-related academic programs, the long-standing pedagogical separation of ship structure and freight management courses has frequently resulted in insufficient comprehensive application skills among graduating students. To address this critical educational gap, this project systematically integrates the two traditionally distinct courses. It reorganizes the core teaching content around the typical, real-world operational tasks of modern shipping companies, thereby fostering a more cohesive learning environment. Furthermore, the curriculum innovatively incorporates Artificial Intelligence Generated Content (AIGC) tools to assist educators in developing complex 3D structural models, dynamic freight simulation scripts, and highly adaptive intelligent question banks. To evaluate the efficacy of this integrated approach, a pilot teaching study was conducted utilizing a rigorous quasi-experimental design. The study comprised a total of 160 students, evenly divided with 80 participants in the experimental group and 80 in the control group. The empirical results revealed that the experimental group achieved an average practical assessment score of 78.4, which was notably 9.2 points higher than that of the control group ($P < 0.001$). Additionally, course satisfaction scores reached 4.21 out of 5 in the experimental cohort, representing a statistically significant increase of 0.47 points over the control group ($P < 0.001$). Ultimately, the integration of AIGC demonstrates significant advantages in enhancing resource development efficiency and student engagement. However, the study also highlights that AI-generated educational content still necessitates meticulous teacher review and professional approval to ensure academic accuracy and industry compliance.

Keywords: industry-education integration; generative ai; maritime education; curriculum development; teaching reform

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1. Introduction

In maritime transportation, ships serve dual functions as structural carriers and cargo containers. For practitioners, possessing only knowledge of hull structures without understanding cargo characteristics, or mastering only loading principles without grasping structural constraints, makes it difficult to perform practical duties effectively [1]. However, domestic maritime institutions have long taught "Ship Structure" and "Freight Management" as two separate courses, leaving students unable to integrate knowledge from both disciplines upon completion. In recent years, some institutions have attempted to merge these courses into a single program titled "Ship Structure and Freight Management," but most implementations merely combine chapters rather than integrating content around real-world operational tasks.

Since 2023, AIGC technologies represented by large language models have rapidly expanded their applications in the education sector, demonstrating high efficiency in text generation, image generation, and 3D model construction. Utilizing AIGC tools for teaching resource development can reduce costs and shorten development cycles, providing new technical solutions for curriculum reform [2]. This paper presents a practical case of an industry-academia collaboration project: merging the courses "Ship Structure" and "Freight Transportation," restructuring the content around real-world enterprise tasks, incorporating AIGC tools to assist in resource development, and evaluating the outcomes through pilot teaching trials.

2. The Practical Basis for Curriculum Reform

2.1. Corporate Research

Prior to the project launch, the research team conducted field visits to 15 shipping companies and ship management firms in Hainan, Guangdong, and Fujian between March and April 2024. These included two large enterprises (over 500 employees), one medium-sized enterprise (100–500 employees), and three small enterprises (under 100 employees). The survey employed a combination of questionnaires and interviews, yielding 142 valid responses and completing interviews with three corporate executives [3].

A prominent finding from the survey revealed that 83.1% of surveyed companies identified the most notable weakness among recent graduates as "fragmented knowledge and inability to apply it comprehensively." A captain with two decades of experience on bulk carriers noted during an interview: "Young professionals today can calculate stability and perform loading calculations, but they struggle to adjust loading plans according to actual cargo conditions while maintaining vessel structural integrity." While 76.8% of enterprises expect new employees to possess both structural analysis and freight planning capabilities, only 28.9% expressed satisfaction or relative satisfaction with graduates' job adaptation speed [2]. Common challenges reported included unfamiliarity with loading software operations (65.5%), lack of intuitive understanding of vessel structural layouts (72.5%), and insufficient systematic analytical skills for complex issues (81.0%).

2.2. Current Course Assessment

The research team conducted a survey on the curriculum design of eight domestic maritime institutions, including three undergraduate and five vocational colleges [2]. By collecting teaching syllabi, consulting with instructors, and observing classes, several prominent issues were identified.

The most critical issue is the "division" of courses. Among the eight institutions, six still offer ship structure and freight management as separate courses, with independent faculty, teaching materials, and assessment systems. When students take the freight management course, they often forget much of the structural knowledge acquired in the previous semester. Even at the two institutions where these courses have been merged into a single subject, instruction focuses solely on ship structure in the first semester and freight management in the second, with no seamless transition between the two semesters [4].

Another issue is the lack of practical components. Hands-on training modules are generally inadequate. Among the eight institutions, only two are equipped with freight loading simulators, while the remaining institutions limit practical courses to teacher-operated demonstrations with student observation. A single loading simulation software package costs hundreds of thousands of yuan, making it unaffordable for most institutions [5].

The third issue is the superficial nature of school-enterprise collaborations. Enterprise experts occasionally give lectures, and students occasionally visit enterprises, but very few enterprises are deeply involved in curriculum design or resource development [6]. This is due to various reasons: enterprises often consider the investment not worthwhile, schools fear excessive corporate involvement might undermine teaching autonomy, and both parties lack a mutually acceptable cooperation mechanism.

2.3. Technical Feasibility

Before deciding to implement AIGC, the research team conducted a comprehensive evaluation of available tools [6]. The assessment criteria were highly practical, focusing on whether the tools could reduce resource development costs and shorten development cycles.

The evaluation concluded that AIGC proves valuable in several areas. For text generation, large language models are used to draft freight case scenarios and exercise drafts, significantly reducing teachers' repetitive work. For 3D modeling, tools leveraging NeRF and 3D Gaussian Splatting technology generate ship hull structure 3D models from basic parameters [7]. Although their accuracy falls short of engineering calculation standards, they are adequate for teaching demonstrations. For exam paper generation assistance, AIGC automatically produces exercises tailored to knowledge points and difficulty levels, enabling teachers to refine them more efficiently.

However, the limitations of AIGC are also evident. Details in 3D models, such as the spacing of support beams and rib configurations, are often inaccurate and require meticulous verification against design drawings. Additionally, cargo routing scripts occasionally contain content that violates maritime regulations [8]. Therefore, it was clearly stated from the outset that AIGC serves only as an auxiliary tool, and all generated content must be reviewed by instructors before being used in classrooms.

3. Course Development Process

3.1. Content Reconstruction

The course is not merely a simple compilation of chapters. Over three months, the research team held repeated discussions with corporate technical experts and frontline instructors to establish a content framework centered around typical work tasks in the shipping industry [9]. The core approach ensures that students naturally apply structural knowledge and freight transportation knowledge while completing specific tasks, rather than learning one subject before moving on to another.

The course is titled "Ship Structure and Freight," with a total of 64 class hours divided into three modules [10]. Module One, "Understanding Ship Structure" (16 hours), covers the names, functions, and layout principles of major structures such as the hull bottom, sides, deck, and bulkheads. Module Two, "Fundamentals of Freight Operations" (16 hours), addresses cargo classification and characteristics, loading principles, and methods for stability and strength verification. Module Three, "Comprehensive Task Training" (24 hours), includes five typical work tasks that students complete in groups of 4–5 members by developing implementation plans. An additional 8 hours are allocated for course assessment.

The five work tasks cover the three main vessel types—bulk carriers, container ships, and liquid cargo vessels—with progressively increasing complexity: development of a loading plan for a 30,000-ton bulk carrier carrying steel; allocation of space on an 1,800 TEU container ship; formulation of a loading and unloading plan for a 5,000-ton oil tanker; emergency response plan for localized structural damage to cargo holds during navigation; and economic benefit analysis for a specific voyage [11].

The teaching process for each task consists of four steps: the instructor distributes the task document and background materials; students research the materials and conduct group discussions to develop preliminary plans; they validate the plans on a virtual simulation platform by inputting the loading plan and verifying whether the floating condition, stability, and structural stresses meet requirements; adjustments are made if necessary; each group presents their plan, followed by joint feedback from the instructor and industry mentors. Taking the first task as an example, students receive the following materials: a general layout diagram of a 35,000-ton bulk carrier, a cargo hold capacity table, hydrostatic curve data, as well as specifications, weights, and port information for a batch of steel materials [12]. Students first determine the loading factor based on steel properties, then allocate cargo across holds according to hold dimensions and deck load-bearing capacity, and finally verify stability and structural strength under both full-load departure and arrival unloading scenarios. Typically, a group needs to make 2–3 iterative adjustments on the platform to satisfy all constraints.

3.2. Using AIGC Tools

The AIGC tools utilized in course resource development and their specific applications are outlined as follows [9].

Three-dimensional model generation. Using an open-source reconstruction tool based on 3D Gaussian Splatting technology, the system generates 3D mesh models of the ship hull, deck layers, and main bulkheads by inputting the fundamental scale parameters from the ship's general layout plan. The research team employed a 35,000-ton bulk carrier as the sample vessel, dedicating approximately six weeks to fine-tuning parameters and workflows. The final modeling process included parameter input, automatic generation of the initial model, manual verification against the general layout plan, error correction, and export. From parameter input to delivery for educational use, the sample vessel required a total of about 25 man-hours (approximately 3 hours for AIGC processing and 22 hours for manual verification), compared to the typical 80 to 120 man-hours required for fully manual modeling [13]. During the development period, three 3D models of representative ship types were completed.

Generation of freight scenario scripts [5]. Utilizing a domestic large language model API, instructors create prompt templates and input elements such as cargo type, vessel parameters, and route conditions. The model then automatically generates scripts containing business context, task requirements, and constraints. During review, instructors prioritize verifying whether the loading complies with standards such as the BC Rules and IBC Rules. A total of 32 initial script drafts were generated during development, with 18 retained after review, resulting in a rejection rate of 43.7%. The primary reasons for rejection were inaccurate descriptions of cargo segregation requirements or loading plans that violated safety regulations.

Development of an intelligent question bank. The teaching and research group identified 86 key knowledge points and used large language models to generate 2 to 3 multiple-choice questions, true/false questions, and short-answer questions for each point [14]. After reviewing, revising, and deduplicating the draft versions, a final question bank comprising 860 items was created (420 multiple-choice questions, 230 true/false questions, and 210 short-answer questions). Among the 86 knowledge points, 79 (91.9%) were covered by questions, while the remaining 7 were excluded due to excessive detail.

The virtual simulation platform has been expanded. The college previously operated a ship virtual simulation teaching platform primarily designed for 3D visualization of hull structures. This update introduces an interactive loading function, allowing students to drag and drop cargo into designated compartments. The system automatically calculates and displays key parameters such as draft, stability height, shear force, and bending moment, while triggering red alerts when limits are exceeded. Technical support for the functionality was provided by the enterprise, while the research team contributed the loading calculation algorithms and validation standards. The entire process, from requirement discussions to system deployment, took approximately four months.

3.3. School-Enterprise Collaboration

The project signed an industry-academia cooperation agreement with Qingdao Borenke International Film, Television and Culture Media Co., Ltd., under which the company provided software usage rights and technical development support valued at 200,000 yuan. The research team also established cooperative relationships with two local shipping companies and one ship management company in Hainan.

Enterprises participated in the revision of the teaching syllabus. In June 2024, the research team organized a syllabus seminar, inviting technical directors from partner enterprises to attend. The enterprises proposed several recommendations: adding content on liquid cargo ship loading (the original plan focused primarily on bulk cargo and containers), incorporating training on voyage economic benefit analysis (a common task for ship management positions), and adopting project feasibility as the primary criterion for practical assessments rather than calculation accuracy. All these suggestions were incorporated into the final version.

Corporate mentors participate in practical teaching. Each semester, 3–4 corporate technical personnel are assigned to the university for guidance. The challenge encountered during implementation was that shipping company staff frequently travel overseas and could not guarantee weekly attendance. To address this, the approach was adjusted to include centralized on-campus sessions (twice per month, each lasting 4 class hours) supplemented by online Q&A sessions. Based on the pilot semester's implementation, this model has largely met the teaching requirements.

The project provided authentic business case studies. The partner enterprises submitted a total of 12 sets of real voyage documentation, including loading plans, loading/unloading records, and voyage reports. All materials underwent data desensitization—removing corporate names, vessel names, commercial freight rates, and modifying certain parameters. The desensitization process for the 12 datasets took approximately two months, exceeding expectations by over a month, primarily due to inconsistent data formats and terminology that required repeated verification with the enterprises.

Student internships at partner enterprises. Upon completion of the course, students are assigned to partner enterprises in batches of approximately 25 individuals each for a two-week internship period. Internship roles include preparing loading plans, conducting vessel inspections, and processing freight documents, with each student supervised by an enterprise mentor. Upon internship conclusion, the mentors evaluate student performance, and these evaluations are incorporated into the final course grade.

4. Teaching Pilot Program and Effect Analysis

4.1. Pilot Design

The course underwent its first pilot phase in the Navigation Technology program, involving 160 students from four classes of the 2023 cohort. A quasi-experimental design was employed: two classes (80 students each) served as the experimental group receiving the integrated curriculum, while the other two classes (80 students each) remained in the control group following the traditional modular teaching approach. Independent samples t-tests revealed no significant differences between the two groups regarding entrance exam scores or prior course performance (entrance exam score: $t = 0.87$, $P = 0.386$; ship principles score: $t = 1.12$, $P = 0.265$), confirming their comparability.

It should be noted that grouping cannot be entirely random—the school does not permit breaking up administrative classes for reorganization; instead, a cluster sampling method is employed, with classes serving as the unit of grouping. This approach may introduce interference from class effects, which will be accounted for in the result analysis.

4.2. Assessment Method

Upon completion of the course, a comprehensive assessment is conducted across three dimensions to evaluate student performance.

Theoretical Assessment (100 points): A closed-book written exam lasting 90 minutes, with questions drawn from a unified question bank distributed according to knowledge points and difficulty levels. Both groups use the same test paper. Question types include 30 multiple-choice questions (2 points each), 10 true/false questions (1 point each), and 3 short-answer questions (10 points each). The exam is scheduled within the same week after course completion, and examination discipline is uniformly managed by the college.

Practical Assessment (100 points): Conducted on a virtual simulation platform over 120 minutes. The task requires students to develop a loading plan for a bulk carrier based on its ship parameters and cargo information for a batch of steel, including cargo distribution across compartments, stability index calculations, bottom plate strength verification, and loading/unloading sequence [9]. Scoring criteria include rationality of the loading plan (30 points), accuracy of stability verification (25 points), accuracy of strength verification (25 points), and standardization of the plan documentation (20 points). Both groups complete the assessment on the same day, using the same platform and facing identical tasks.

Comprehensive Competency Assessment (100 points): Enterprise mentors and course instructors each contribute 50% to the evaluation. Assessment dimensions include problem analysis ability (25 points), solution feasibility (25 points), teamwork (25 points), and oral communication skills (25 points). The evaluation is based on the presentation and defense performance during the comprehensive task training session [6]. Enterprise mentors employ a single-blind method, being unaware of which group their students belong to; however, the rigor of this method is limited due to their prior involvement in teaching guidance for the experimental group.

Upon completion of the course, a satisfaction questionnaire (5-point scale) was distributed to all students, covering four dimensions: course content, teaching methods, practical components, and overall satisfaction. The questionnaire consisted of 16 items and was anonymous. A total of 160 copies were distributed, and 152 valid responses were collected, resulting in a response rate of 95.0%.

4.3. Results

Table 1 compares the assessment scores across all dimensions between the two student groups.

Table 1. Comparison of Assessment Scores and Satisfaction between the Experimental Group and the Control Group

Evaluation Item	Experimental group (n=80)	Control group (n=80)	statistics	P price
Theoretical Assessment/Score	75.6 ±8.3	72.8 ±9.1	t=2.03	0.044
Practical Assessment / Points	78.4 ±7.6	69.2 ±10.5	t=6.34	<0.001
Comprehensive Competency Score/Points	73.8 ±9.2	66.5 ±10.8	t=4.61	<0.001
Course Satisfaction/Score	4.21 ±0.53	3.74 ±0.68	t=4.85	<0.001

Table 2 presents the scores for each component of the practical assessment.

Table 2. Comparison of Scores for Each Sub-Item in the Practical Assessment

Practical Assessment Items	Experimental Group/Component	Control Group/Group	Difference/Point	P price
Rationality of the loading plan (30 points)	23.1 ±3.2	19.5 ±4.6	+3.6	<0.001
Stability verification accuracy (25 points)	19.8 ±2.8	17.6 ±3.5	+2.2	0.001
correctness of strength verification (25 points)	18.5 ±3.1	15.2 ±4.2	+3.3	<0.001

Standardization of the solution document (20 points)	17.0±2.4	16.9±2.5	+0.1	0.793

4.4. Result Analysis

The gap between the two groups in the theoretical assessment was minimal (2.8 points, P=0.044). This result was expected as both groups used identical teaching materials and covered the same scope of knowledge. The advantage of the integrated curriculum lies not in memorizing individual knowledge points but in their comprehensive application [9].

There was a significant gap in the practical assessment scores (9.2 points, P<0.001). Specifically, the deficiencies were concentrated in the rationality of the loading scheme (+3.6 points) and the accuracy of strength verification (+3.3 points). This aligns with the course design intent: the experimental group underwent repeated training on the complete process of "structural constraints → loading scheme → adjustment and validation," whereas the control group, taught in discrete modules, often focused solely on loading calculations during practical exercises while neglecting structural considerations. The standardization of the design documentation showed no significant difference between the two groups (+0.1 points, P=0.793), as both received identical writing training in other courses.

Regarding enterprise mentor evaluations, the experimental group scored an average of 76.3±8.7 points, compared to 68.1±10.2 points in the control group, indicating a difference of 8.2 points (P<0.001). Based on the passing score threshold (≥75 points), the pass rate was 71.4% in the experimental group versus 58.8% in the control group ($\chi2$=3.92, P=0.048). The research team reviewed internship performance records from previous cohort students (Class of 2022) in the same major, which showed a 58.8% pass rate comparable to the current control group. Given that admission scores and prerequisite course performance were similar across both cohorts, the improvement in the experimental group can be partially attributed to curriculum reforms [13]. However, it should be noted that some enterprise mentors participated in teaching activities for the experimental group, limiting the rigor of the blinding protocol; thus, the reference value of this metric warrants cautious evaluation.

In terms of satisfaction, the experimental group scored higher than the control group across all four dimensions: course content (4.32), teaching methods (4.28), practical components (4.15), and overall satisfaction (4.21) (control group scores: 3.81, 3.69, 3.65, 3.74 respectively), with all differences being statistically significant (P<0.001). Regarding open-ended questions, the most frequently cited positive feedback from the experimental group included "the content is closely aligned with real-world applications," "the virtual training was highly rewarding," and "the insights provided by industry mentors were practical"; in contrast, the control group primarily reported issues such as "the connection between the two courses was unclear," "limited practical opportunities," and "uncertainty about how to apply what they learned."

5. Reflection and Discussion

5.1. Effective Practices

The approach of organizing course content around work tasks achieved the desired outcomes. The five tasks covered three different ship types with progressively increasing difficulty, enabling students to naturally integrate knowledge from both domains during task completion. The virtual simulation platform's real-time feedback mechanism also received positive student evaluations—the system issued red alerts when solutions were inadequate, allowing students to make repeated adjustments and establish a clear cause-and-effect relationship between plans and results. One student commented post-class: "I adjusted the loading plan three times before it was approved on the platform. Although it involved some effort, it left a much deeper impression than simply attending lectures."

5.2. Shortcomings

The engagement level of corporate mentors remains inconsistent. Due to the frequent overseas voyages of maritime personnel, the originally planned weekly campus visits could not be implemented and were adjusted to a combination of in-person and online sessions. However, the effectiveness of online interactions was significantly inferior to face-to-face meetings. Future efforts will involve coordinating with enterprises one semester in advance to schedule mentors' campus availability and transitioning some guidance sessions to video recordings for feedback delivery.

The data desensitization cycle exceeded expectations significantly. The desensitization of 12 corporate datasets took two months, with the majority of time spent verifying data meanings and modifying commercial information. Moving forward, standardized desensitization procedures and templates should be established to reduce communication costs.

The issue of fairness in the control group emerged as a concern. After the pilot phase concluded, students from the control group expressed their desire to use the virtual simulation platform as well. This constitutes an ethical concern inherent in quasi-experimental designs. Following the completion of the pilot, the control group was granted access to the platform, and four instructional hours of supplementary practical training were arranged.

5.3. The Boundaries of AIGC

After a semester of application, the research team developed a clearer understanding of the capabilities and limitations of AIGC.

AIGC excels in the "from 1 to N" approach—by providing templates and parameters, it rapidly generates numerous pieces of content with similar structures but varying details. For instance, generating 32 distinct scripts for different ship types and cargo loads from a single freight script template significantly reduces redundant work.

The area requiring improvement is the "from 0 to 1" process—creating entirely accurate and professionally compliant content from scratch, which remains unachievable at present. Among the 32 freight manifests, 14 (43.7%) contain professional errors requiring elimination or significant revisions, including inaccurate cargo isolation requirements, loading violations of the BC Rules, and outdated references to stability parameters. Regarding the 3D models, the hull shell and main decks are generally accurate, but details such as reinforcement materials, elbow plates, and piping often contain inaccuracies.

In summary, AIGC in this project serves as an efficiency tool rather than an intelligent teaching assistant. It assists educators in drafting resources more efficiently, while the final quality assurance remains dependent on professional judgment. In highly specialized fields like maritime education, using AIGC to replace human instructors is unrealistic given current technological capabilities.

It is noteworthy that AIGC tools also require specific hardware resources. 3D model generation necessitates GPU server support, and this project utilizes cloud-based GPU instances provided by the enterprise. Self-deployment by academic institutions would entail significant hardware investment [3]. The API fees for large language models are charged per token; during the development phase, API usage for script generation and question bank construction amounted to approximately ¥3,000. Although this cost is substantially lower than manual coding expenses, it must still be factored into budgets for projects with limited funding.

6. Conclusion

This project integrates the two courses on ship structure and freight transportation, reorganizes the teaching content around real-world corporate tasks, and utilizes AIGC tools to develop three 3D models, 18 freight-related scripts, and 860 practice questions.

During the pilot teaching phase, the experimental group demonstrated significantly better performance than the control group in practical assessment (+9.2 points), comprehensive competency evaluation (+7.3 points), and course satisfaction (+0.47 points).

Practical experience indicates that an integrated curriculum design centered on work tasks effectively enhances students' ability to apply knowledge comprehensively. AIGC provides substantial value in improving resource development efficiency, although the accuracy of generated content still necessitates teacher oversight. The next phase will focus on piloting and expanding the initiative across additional institutions while refining the quality control processes for AIGC-generated content.

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