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Article

A Study of Small-Scale Aircraft Carrier Modelling in Educational Practice

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Abstract: The oceans boast abundant resources, making the ocean economy a crucial global component. Consequently, the training of personnel in marine engineering is paramount. Practical courses play a pivotal role in this professional learning journey. However, several colleges and universities struggle to offer practical courses due to resource constraints and other challenges. Ship modelling emerges as a promising solution to overcome these limitations, offering a cost-effective practical learning approach. This paper employs a task-based teaching method to investigate the practical education of undergraduate marine engineering students, utilizing the ship working group of the Poetic Marine Engineering Team at Guangdong Ocean University, with aircraft carrier modelling as the focal point. The findings reveal that learners participating in ship modelling practical classes exhibit enhanced abilities across various domains, including professional knowledge, skills, future planning, and innovation. This study holds implications for learning within the marine engineering field.

Keywords: Ship modelling; Poetic Marine Engineering Team; Task-based teaching method; Aircraft carrier modelling

1. Introduction

The ocean, as Earth's vast expanse, holds a wealth of resources waiting to be tapped [1,2]. With the rapid advancement of science and technology, humanity's understanding of the oceans has deepened considerably, paralleled by significant strides in marine engineering

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[3-5]. From the exploration and extraction of marine oil [6] and natural gas [7] to deep-sea scientific research [8], resource utilization [9], environmental protection [10], and disaster prevention [11], marine engineering stands as a pivotal pillar supporting the growth of the marine economy.

The nurturing of talent in marine engineering has become increasingly crucial, given its critical role in various industries [12]. Many maritime-focused colleges and universities globally prioritize ship-related courses in their curriculum. However, numerous institutions encounter challenges such as limited professional resources and safety concerns. Consequently, students often lack practical experience with real ships and may miss opportunities to engage in actual ship construction processes. Without hands-on experience, students' understanding of ship components remains largely theoretical [13-15]. It's noteworthy that ship-related theories are intricate and interdisciplinary, encompassing fluid mechanics [16,17], mechanics of materials [18], artificial intelligence [19], mechanical drawing, and mechanical design [20]. Building ship models can significantly enhance students' hands-on abilities. Moreover, these models often exhibit a degree of similarity to actual ships, aiding students in better comprehending theoretical knowledge by providing tangible examples.

Shipbuilding is a vast and intricate domain, and the absence of practical exposure can hinder students' readiness for future endeavors in the field [21,22]. Therefore, addressing this gap by enhancing access to real-world engineering practice is essential for fostering well-rounded and competent marine engineers.

The project-based learning (PBL) approach advocated by Vervoort et al. fosters the comprehensive development of marine engineering students by integrating scientific inquiry with educational practices. This method not only enhances technical expertise but also cultivates vital social competencies such as teamwork, effective communication, and adept problem-solving skills [23]. Leon and Marta conducted an assessment of the efficacy of teaching shipbuilding principles within an undergraduate maritime engineering course at the Polytechnic University of Catalonia (UPC), Spain, amidst the challenges posed by the COVID-19 pandemic. Employing gamification tools such as "Kahoot!", "Mentimeter," and "Socrative," alongside varying levels of learning complexity, they sought to evaluate the impact on student outcomes. Despite enhancing student engagement and fostering a positive classroom environment, the results indicated that gamification did not yield a significant improvement in overall academic performance [24]. Kandemir et al. devised an evaluation framework utilizing the Technique of Ideal Solution Sorting Preferences (TOPSIS), aligning it with the minimum competency standards outlined in the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW). This system was piloted with 16 maritime engineering students within team-based contexts, across various scenarios. The findings underscored the significant enhancement of learning outcomes, teacher proficiency, and the refinement of curriculum and infrastructure. Moreover, the versatility of this assessment system suggests its potential applicability to practical research across diverse disciplines [25]. Mora et al. implemented a problem-based learning (PBL) strategy integrating mobile devices and internet tools to bolster students' selfdirected learning abilities, teamwork dynamics, and practical problem-solving capabilities. They structured three distinct active learning settings to encourage collaborative work and the utilization of technological resources for knowledge acquisition and problem resolution, employing challenge-based learning, project-based learning, and problem-based learning methodologies. Despite encountering certain obstacles, the study demonstrated notable improvements in students' motivation and self-efficacy levels [26].

After a comprehensive examination, it becomes apparent that practical work holds a pivotal role in the execution of marine engineering-related programs. However, the majority of current teaching practices heavily rely on virtual platforms. While convenient, these platforms noticeably lack realism and immersion, posing challenges for students to attain an immersive learning experience. In contrast, ship modelling stands out as an economical, scientific, and realistic practical activity with significant potential to overcome the limitations of virtual platforms. Therefore, the aim of this paper is to delve deeply into the facilitating role of ship modelling practical activities in ship-related courses, employing a task-based learning method (TBL). The objective is to offer valuable insights and lessons to enhance teaching practices in this domain. Figure 1 shows the flowchart of this paper.

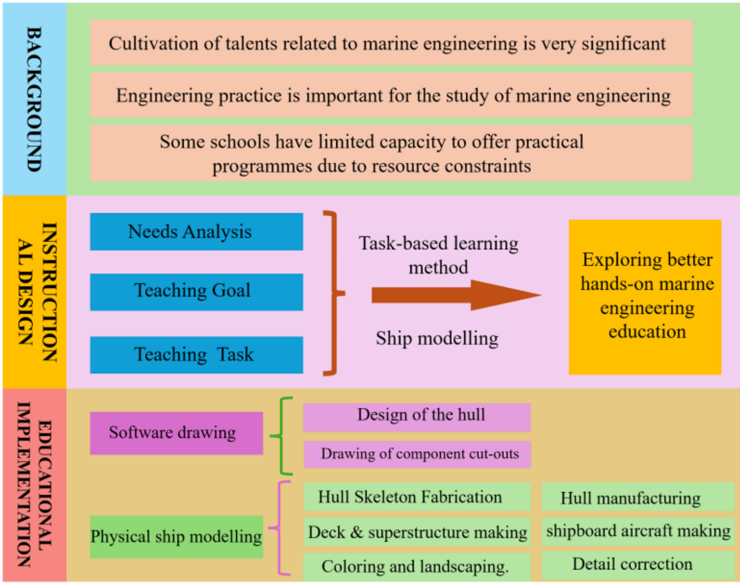

Figure. 1. Flowchart for this paper.

2. Methodology

The Task-Based Learning (TBL) method is an instructional model that prioritizes student-cantered learning by structuring specific, achievable tasks for students to accomplish in order to acquire knowledge. Although commonly associated with language education, TBL has found application in engineering education due to its efficacy in training students to learn from problem-solving and its practicality. Leveraging this method, this paper aims to explore an effective approach to enhance the teaching outcomes of ship-related courses within the context of ship modelling. For the focus of this paper, instructional design is structured around three fundamental components: needs analysis, setting instructional goals, and establishing instructional tasks. These elements are interconnected and mutually supportive, collectively constituting a robust instructional design system.

2.1 Needs analysis

A survey conducted among Chinese higher education institutions offering marine engineering-related programs indicates a prevalence of theoretical studies, with a scarcity of practical courses. Notably, several non-key universities encounter difficulties in offering ample practical opportunities due to resource constraints. Considering these challenges, the primary needs identified encompass the development of professional skills, the cultivation of innovative thinking, the optimization of resource requirements, and the reinforcement of theoretical knowledge, as shown in Figure 2.

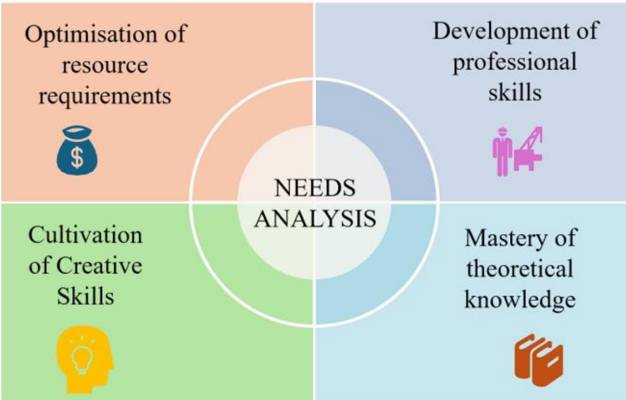

Figure. 2. Learning needs of the programme.

2.2 Setting teaching goals

Based on the needs analysis, the following teaching objectives are formulated in this paper.

(1) Enhance learners' further knowledge of the major.
(2) Enhance learners' relevant professional skills.
(3) Enhance scholars' mastery of their expertise.

2.3 Establishing teaching tasks

In this paper, the process of building a complete aircraft carrier model is split into the following two teaching tasks.

(1) Based on publicly available parameters, learn to draw aircraft carrier related structures using relevant software.
(2) Making physical ship models with limited resources

3. Educational implementation

This paper draws upon the ship modelling studio operated by the Poetic Marine Engineering Team at Guangdong Ocean University as the experimental site. Five learners from the Department of Marine and Ocean Engineering, spanning the academic years 2021 to 2022, were selected to participate in the teaching activities. The specific tasks to be taught and the knowledge and skills that learners can acquire during the tasks are shown in Figure 3.

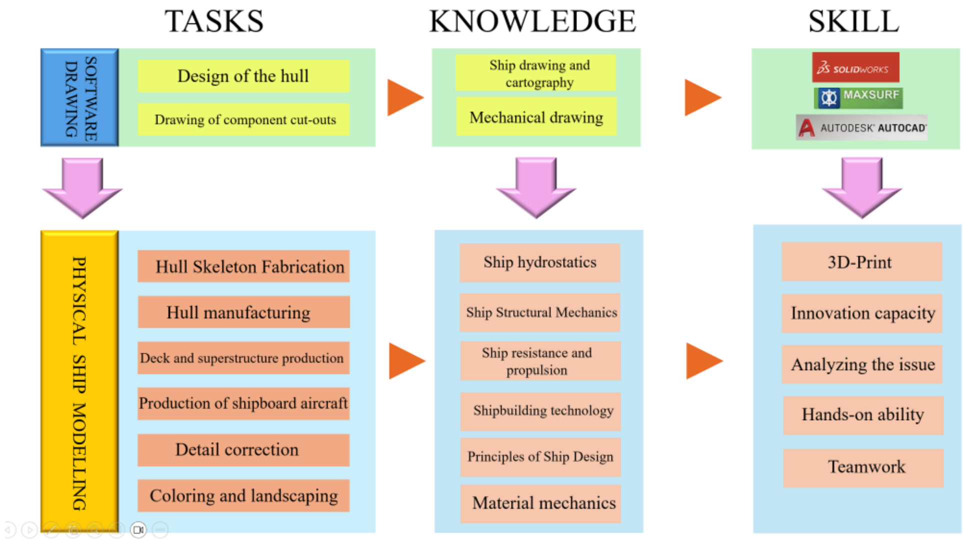

Figure. 3. The specific tasks to be taught and the knowledge and skills that learners can acquire during the tasks.

3.1 Software drawing

This teaching task is divided into two projects: one focuses on learning ship modelling using modelling software, while the other involves mastering the drawing of cut parts for the keel and ribs derived from the constructed model.

In this context, two modelling software are utilized: MAXSURF and SolidWorks. MAXSURF is a professional ship modelling software known for its flexibility and robust surface modelling capabilities, making it ideal for constructing the hull of the ship. On the other hand, SolidWorks excels in creating intricate parts and offers a diverse array of design tools, making it suitable for building both the superstructure of the ship and various outfitting components.

3.1.1 Design of the hull

Using MAXSURF's Modeller module, the hull is constructed based on the line graph derived from publicly available parameters. Hull form lines as shown in Figure 4. Initially, the de-panel is formed, followed by closing the control points at both ends. Subsequently, by switching between the three views and adjusting the control points, the hull's profile is modified, and the surface smoothness is refined to achieve a smoother surface, resulting in the ship's hull, as depicted in Figure 5.

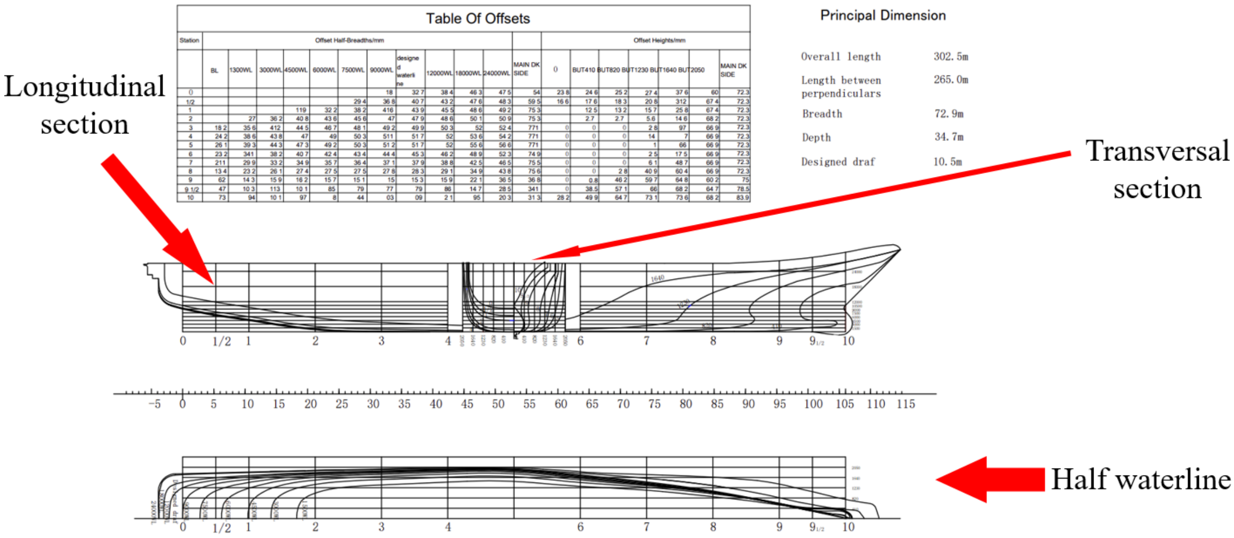

Figure. 4. Hull form lines

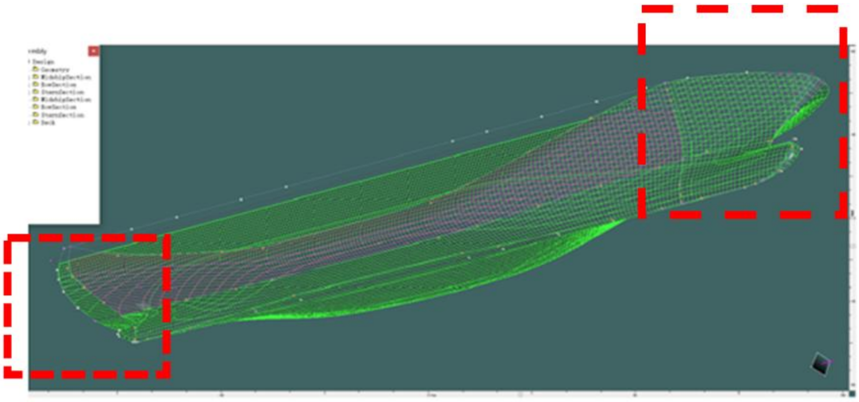

Figure. 5. Finalizing the hull in MAXSURF.

The constructed hull shell from MAXSURF is then imported into SolidWorks, where the superstructure and outfitting parts are further refined with reference to the three-view representation of the aircraft carrier. The model is rendered, producing both a structural drawing and a 3D rendering of the model.

Through this iterative process, learners not only gain proficiency in MAXSURF software and 3D modeling skills but also enhance their comprehension of hull shapes, spatial imagination, problem-solving abilities, and the qualities of diligence and patience. These acquired skills and attributes are integral for their future academic and professional endeavors.

3.1.2 Drawing of component cut-outs

To create the cutting diagram for the components, namely the keel and rib plates, the process involves drawing out the expansion diagram based on the ship model. Using SolidWorks software's engineering drawing function, the hull is projected in each view, and the ribs of the hull are projected in each section. Subsequently, the engineering drawings are exported to DWG format and imported into AutoCAD for further refinement.

In AutoCAD, the drawings undergo layer simplification, removal of redundant lines, and retention of only the essential skeleton. This process streamlines the drawings, ensuring clarity and precision in the representation of the keel and rib plate expansion diagrams.

During the creation of component cutting diagrams, learners acquire skills in generating 2D engineering drawings from 3D models by utilizing SolidWorks' engineering drawing function to extract the ship model. They also learn to simplify layers and manage lines in AutoCAD, retaining only the essential skeleton components. A schematic diagram of the slotted cut is shown in Figure 6.

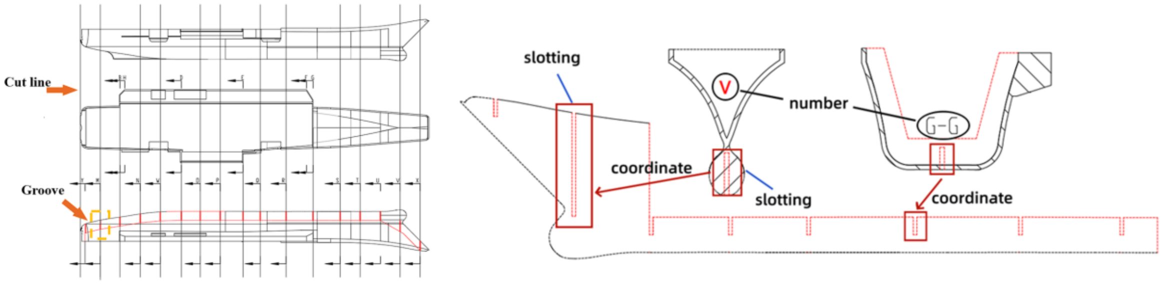

Figure. 6. Schematic diagram of slotted cut.

Moreover, this hands-on process enhances learners' spatial imagination, problem-solving abilities, and drawing skills. It establishes a robust foundation for their future academic and professional pursuits, empowering them with valuable practical skills and knowledge.

3.2 Physical ship modelling

Based on the software drawing outcomes, the construction of the ship's solid model proceeds with seven distinct projects. These projects include skeleton creation, hull creation, deck and superstructure creation, shipboard aircraft creation, detail correction, coloring, and landscaping.

3.2.1 Hull Skeleton Fabrication

The fabrication of the hull skeleton comprises crafting the hull keel, the hull ribs, and their respective components. To balance the hull's strength with the economic constraints of the practical course, cardboard is employed as the primary fabrication material for the ship skeleton. Specifically, 2mm thickness cardboard is selected for crafting the ribs, while 3mm thickness cardboard is used for the main keel. This choice ensures a sturdy structure while maintaining cost-effectiveness.

(1) Ship keel production

The keel serves as a crucial component running along the hull, connecting the bow and stern pillars as well as each rib plate. It stands as the cornerstone of the ship's skeleton. However, due to material size constraints, we needed to divide the keel into two sections. The outlines of these sections were depicted in separate drawings, which were then affixed onto 3mm cardboard. Subsequently, the keel was meticulously cut out from the cardboard, adhering to the outlines delineated in the drawings, as shown in figure 7.

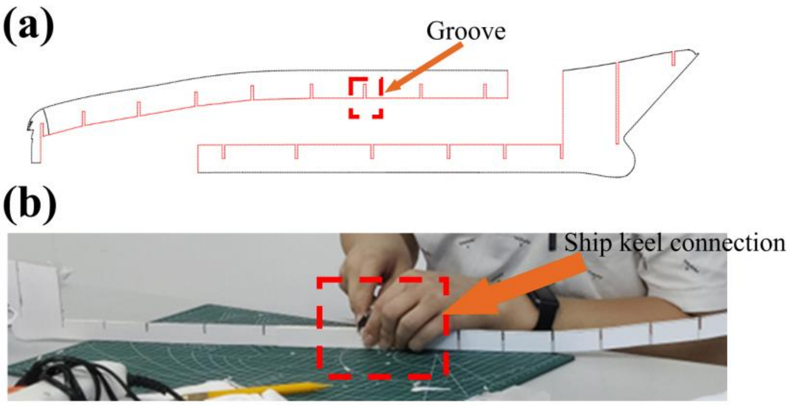

Figure. 7. Ship keel. (a) Outline of the keel. (B) Physical appearance of the keel.

(2) Hull rib production

Hull ribs play a critical role in shaping the overall structure of the ship during construction, directly influencing the ship's profile. They are essential for ensuring the smoothness and accuracy of the hull's curvature. In areas where the hull curvature varies significantly, it may be necessary to increase the number of rib plates to effectively capture and express these changes. The process of creating rib plates follows a similar approach to that of the keel, involving careful drawing of outlines onto cardboard sheets and precise cutting to fabricate the ribs according to the ship's design specifications, as shown in Figure 8.

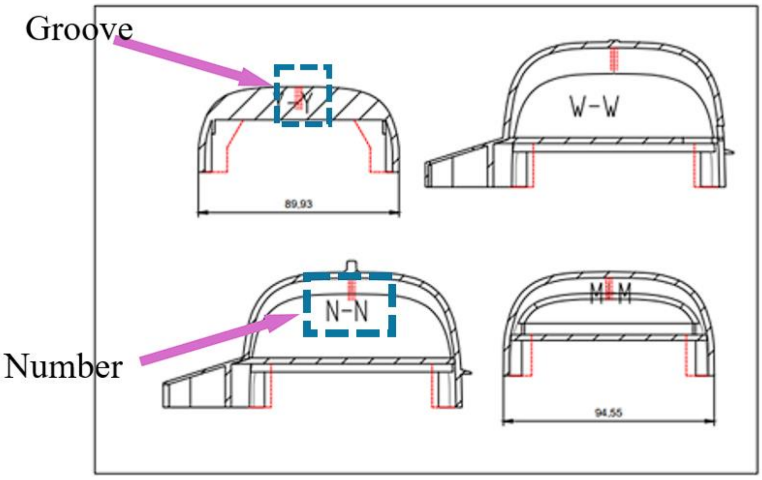

Figure. 8. Ribbed plate.

(3) Splicing frame

The rib plates are sequentially numbered in accordance with the rib numbers indicated on the ship design drawings. They are then affixed to the keel in numerical order, starting with the uppermost rib plate. Due to inherent tolerances in hand cutting, additional steps such as edge sanding and hole enlargement may be necessary in certain areas to ensure proper fit and alignment.

During the construction of keel and hull parts, learners gain a profound understanding of the critical significance of precision control and material strength. As hand-cutting techniques have inherent limitations in precision, learners must acquire the skill of making manual adjustments during the assembly process. This necessitates keen observation, precise adjustments, and a patient dedication to ensuring meticulous quality. It serves as an exercise in honing their observational skills and adaptability while also testing their patience and commitment to achieving excellence. As shown in Figure 9.

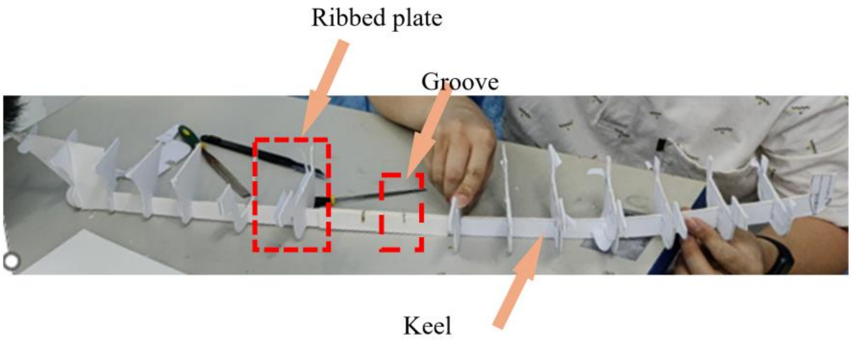

Figure. 9. Hull frame.

3.2.2 Hull manufacturing

The hull manufacturing process encompasses several crucial steps, including the application of the hull skin, the meticulous construction of the bulbous nose bow, and Watertightness and strength enhancement. These measures are essential for guaranteeing the stable navigation of the ship model.

(1) Hull skinning

The core aspect of boat hull construction lies in the process of skinning the skeletal frame of the boat model. This method draws inspiration from traditional wooden boat building techniques, where thin strips of flat wood are carefully fitted onto the hull skeleton and securely glued. This meticulous process ensures complete coverage of the hull, forming its shape and structure. A flow chart of the skinning is shown in Figure 10.

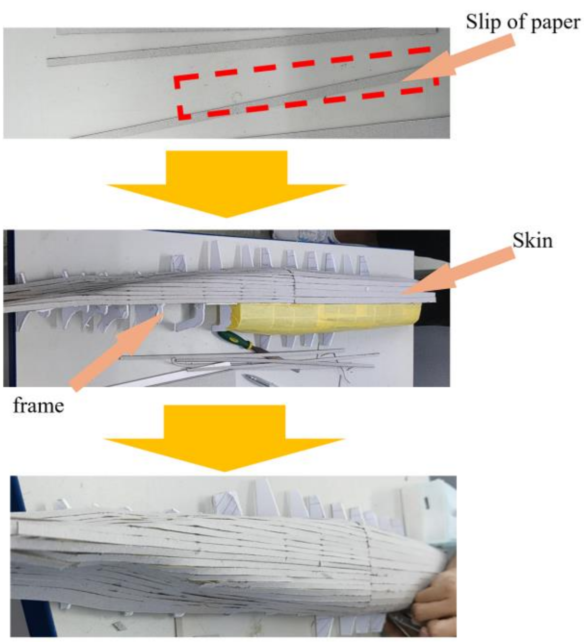

Figure. 10. Flow chart for skinning.

(2) Bulbous Bow Production

The bulbous bow is a crucial design feature for ships, and its construction often relies on specialized materials such as AB Patch. This material boasts exceptional characteristics, including high plasticity, minimal shrinkage after curing, superior adhesion and strength. These properties make it particularly well-suited for modeling and prototyping purposes, enabling precise and durable construction of bulbous bows to enhance ship performance. Bulbous Bow is shown in Figure 11.

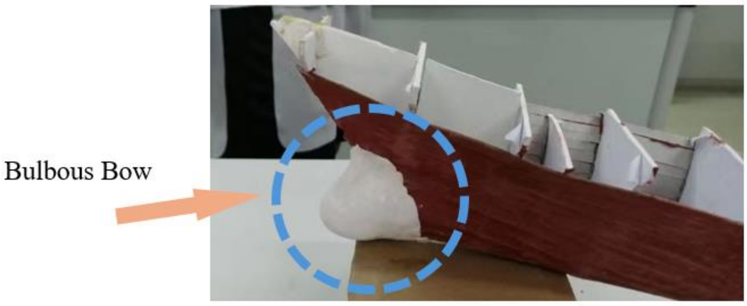

Figure. 11. Bulbous Bow.

(3) Watertightness and strength enhancement

Following the completion of the hull skin, a special automotive-grade atomic grey paint is selected and evenly applied to the hull to fulfill requirements for strength, waterproofing, and aesthetics. This material offers advantages such as affordability, rapid curing, high post-curing strength, excellent waterproofing properties, and ease of sanding. However, since the main material of the hull is cardboard, which lacks sufficient strength, and the atomic grey paint may experience slight shrinkage during the drying process, small pits may appear on the surface of the hull.

After thorough reflection and discussion among the learners, a decision is made to address this issue by using quick-drying water-based patching clay. This material boasts faster drying times compared to the automotive-grade atomic grey paint and is suitable for filling small pits. The pits are meticulously repaired and sanded repeatedly until the hull achieves a smooth finish.

Boat hull construction transcends mere craftsmanship; it represents a holistic learning journey that fosters the development of learners' skills across various domains. Throughout this process, learners have the opportunity to refine their craftsmanship, master material handling techniques, cultivate innovative design thinking, sharpen spatial perception, hone problem-solving skills, and nurture patience.

Engaging in boat hull making enables learners to immerse themselves in a hands-on learning experience that transcends traditional education. It encourages them to experiment, adapt, and overcome challenges, thereby fostering a deeper understanding of not only the technical aspects of boat building but also the broader principles of creativity and resilience. Ultimately, this comprehensive learning process equips learners with a diverse set of skills that are invaluable both within and beyond the realm of boat construction.

3.2.3 Deck and superstructure production

(1) Desk production

There are several problems with the decking process, including the following.

a) How to mount the deck so it doesn't interfere with the cabin layout?

b) The thickness of cardboard presents a challenge for crafting a skidding deck. How might this issue be addressed?

Based on the aforementioned issues, learners have put forward a method to transform the primary deck into one adhered by magnetic suction. This involves embedding N52 magnets within both the hull and the deck, allowing for easy access to the deck while maintaining the aesthetic appeal of the ship model. As for the second issue, the learners have suggested a technique involving the layering of multiple thin cardboard sheets. Initially, the first layer of cardboard is affixed, followed by the determination of the warping angle, and subsequently, the stacking and adherence of subsequent layers to ensure parallel alignment with the main deck.

(2) Production of superstructures

For an aircraft carrier, the superstructure encompasses the island section. Crafting the main body of the ship's island relies heavily on modeling drawings. This process involves software projection of the engineering drawings of its diverse surfaces, creating plane cutting diagrams, and then transferring these diagrams onto cardboard. Each surface is meticulously cut and assembled, forming individual parts that collectively compose the island structure.

Throughout this project, learners glean invaluable lessons in disassembly and reassembly strategies, creative problem-solving, meticulous material selection, precise positioning techniques, patience, and a diligent work ethic. They develop flexibility in problem-solving and integrate practical experience with theoretical learning, fostering a holistic understanding of the project's intricacies.

3.2.4 Production of shipboard aircraft

The production of the ship's aircraft is streamlined through the utilization of 3D printing technology, encompassing three key stages: modeling, printing, and post-processing. The 3D printing flowchart is shown in Figure 12.

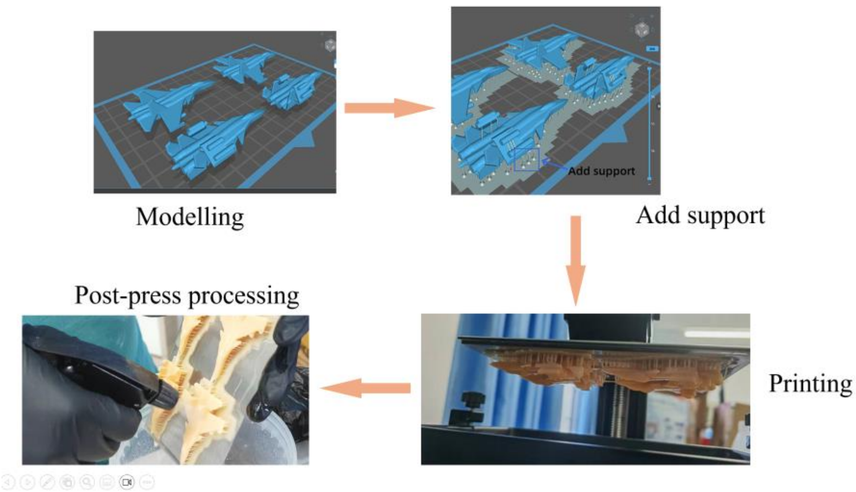

Figure. 12. 3D Printing Flowchart

(1) Modeling

The carrier's naval aircraft underwent modeling using SolidWorks modeling software, where they were meticulously scaled to match model proportions. Subsequently, the scaled models were converted into STL print format, preparing them for the 3D printing process.

(2) Printing

The fundamental principle of 3D printing technology involves importing a digitized three-dimensional model into specialized software, which then dissects it into numerous microscopic layers or sections, akin to the concept of integration in advanced mathematics. Subsequently, this processed file is imported into a 3D printer, initiating the construction of the object layer by layer based on these segmented data.

The operational process typically entails importing the file into slicing software such as CHITUBOX for segmentation. Initially, adjustments are made to the print placement to ensure it fits within the printing surface, while also optimizing the layer pattern for the final print. Additionally, print supports are added to mitigate the risk of warping during the printing process, which could lead to print failures.

Ultimately, the model is sliced to prepare it for 3D light-curing printing, a layer-by-layer approach. This pre-processing step is crucial for ensuring optimal printing results. Once slicing is complete, the file is exported for direct printing.

(3) Post-processing

Post-printing treatment is crucial for ensuring the quality and durability of the printed models. After light-curing printing, the model may retain a small amount of resin suspension, typically resulting in a grayish appearance. To address this, the printed model should be thoroughly cleaned with a solution containing over 95% alcohol. Subsequently, soaking the model in water effectively washes away any excess resin.

To enhance the strength of the printed parts, secondary curing is necessary. This involves placing the parts in an ultraviolet curing box and subjecting them to a secondary curing process. Typically, the parts are cured for approximately 60 seconds to achieve optimal results. Following curing, any support structures can be safely removed, and the model is ready for further processing or use.

3.2.5 Detail correction

This project encompasses three key components: propeller fabrication, island outfitting, and bilge keel fabrication. Propeller fabrication and island outfitting leverage 3D printing technology for precision and efficiency. As for the bilge keel, its primary function is to enhance the ship's damping during transverse rocking, thereby reducing amplitude and increasing stability. The bilge keel is crafted by cutting a long, slender strip to size, trimming it accordingly, and affixing it along the centerline of the hull below the waterline.\

3.2.6 Coloring and landscaping

The comprehensive process of coloring a model involves the utilization of various tools and materials such as air pumps, spray pens, gas masks, gloves, and model paints. Due to the potential toxicity of the paint and particles during spraying, special precautions are essential, hence the necessity of gas masks.

Initially, a uniform layer of water-based patching paint is sprayed onto the model to enhance paint adhesion and establish a consistent base color. Spray cans are ideal for large-area patching due to their wide coverage and ease of operation.

For scene production, particularly creating a sea-driving scene, materials include PVC board, water scene paste, shaping knife, and more. The primary technique involves layering the water scene paste and employing various techniques to simulate the appearance of the sea. Subsequently, white waves are meticulously added to enhance the effect of the ship model navigating through the sea.

4. Result

The performance of the five learners who participated in the observed teaching session, as well as their subsequent performance at the end of the teaching, highlights several noteworthy phenomena.

(1) In theoretical mechanics, hydrodynamics and ship structural mechanics, where the failure rate is close to 50%, these five students have achieved excellent results.
(2) From studying and modeling, all five participants found their own interests and research directions.
(3) The software skills and creativity acquired by the five learners during this teaching session provided them with a competitive advantage in relevant competitions.

5. Conclusion

Task-driven learning within the realm of ship modeling offers significant advantages in undergraduate marine engineering education. By actively engaging in the design and production of ship models, students not only deepen their understanding of marine engineering principles and technologies but also foster interdisciplinary thinking and enhance their practical skills. This hands-on approach to learning ignites students' interest and motivation, prompting them to delve deeper into relevant knowledge areas.

Moreover, ship modeling underscores the importance of teamwork and communication, essential skills for any marine engineer. Collaborative efforts in model creation cultivate students' team spirit and communication abilities, preparing them for the collaborative nature of real-world engineering projects.

Furthermore, ship modeling seamlessly integrates theory and practice, allowing students to apply theoretical knowledge in practical scenarios. This bridge between theory and application enhances the overall quality of education and equips students with valuable practical skills.

Ship modeling has the advantages of low cost, low technical requirements, and high practicability, providing a low-cost and efficient way of teaching for some underfunded institutions.

In summary, the task-driven learning approach facilitated by ship modeling injects vitality into undergraduate marine engineering education, nurturing professionals with comprehensive competencies and a competitive edge in the field.

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