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Exploration and Practice of Innovative Practical Ability Cultivation Model for Marine Science Undergraduates

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Abstract

With the in-depth implementation of China's "Maritime Power" strategy, there is an increasingly urgent demand for marine professionals who possess both solid theoretical foundations and outstanding innovative practical abilities. Traditional teaching models focusing primarily on theoretical instruction can no longer meet the requirements for cultivating interdisciplinary and innovative talents in the new era. This paper systematically explores and constructs a novel "Teaching-Research-Industry" triple helix-driven cultivation model to address prominent issues in current marine education, including the disconnection between theory and practice, limited coverage of research training, and insufficient alignment with industry needs. The model deepens classroom reform through project-based teaching, broadens students' horizons by leveraging research platforms, and enhances students' ability to solve complex engineering and scientific problems through industry-education integration in real-world projects, while ensuring cultivation quality through a comprehensive, diversified evaluation system. Four years of practice has demonstrated that this model effectively stimulates students' innovative potential, significantly improves their hands-on skills, teamwork, and comprehensive innovative abilities, with a threefold increase in awards won in technological innovation competitions and notable enhancement in employment competitiveness, providing valuable references for marine talent cultivation in similar institutions.

Keywords: marine science, innovative practical ability, cultivation model, industry-education integration, teaching reform, triple helix model

1. Introduction

The ocean represents a strategic frontier for high-quality development and serves as a new blue space supporting future growth. According to the "2023 China Marine Economy Development Report," China's marine economy has exceeded 9.8 trillion yuan, accounting for 7.8% of GDP, with demand for high-quality marine science and technology professionals experiencing exponential growth. Marine-related programs in higher education institutions bear the critical responsibility of cultivating and supplying innovative talents at the forefront of marine science and technology. However, China's marine education has long exhibited a tendency to "emphasize theory over practice and prioritize knowledge transmission over ability development"[1], resulting in a significant gap between cultivated talents and industry requirements.

Marine program students typically possess strong mathematical foundations and professional knowledge, yet demonstrate notable adaptation challenges when confronted with real-world marine environments, complex instrumentation, and practical industry problems: (1) inadequate hands-on skills and operational proficiency with advanced marine observation equipment; (2) deficiency in innovative thinking when addressing complex marine challenges; and (3) prolonged industry adaptation periods, requiring 6-12 months on average to achieve full job competency. These issues substantially constrain the development pace and quality of China's marine science and technology sector.

Three primary factors contribute to these challenges: (1) Instructional aspects: Verification-based experiments dominate over 70% of laboratory courses, with severe shortages in design-oriented and comprehensive experiments. Curriculum updates lag behind technological advancements, taking 3-5 years on average to incorporate cutting-edge marine technologies. (2) Research aspects: High-level research activities primarily involve graduate students and select undergraduates, with only about 15% of undergraduates participating in research projects, failing to effectively translate research advantages into teaching resources. (3) Industry aspects:

Industry-academia collaboration remains superficial, with 73% of student internships limited to observational visits and basic operations rather than substantive engagement in solving core technical problems.

To address these issues, we initiated a systematic reform of the talent cultivation model in 2020, adopting a student-centered, Outcome-Based Education (OBE) approach[2]. This paper comprehensively elaborates the conceptual framework, implementation pathways, and practical outcomes of this innovative practical ability cultivation model, aiming to provide transferable experience for peer institutions.

2. Construction of the "Teaching-Research-Industry" Triple Helix-Driven Cultivation Model

This study draws on the Triple Helix Model[3] from innovation theory to construct a cultivation model centered on the interaction among three key stakeholders: universities, industry, and government (as policy and environmental supporters). The theoretical foundation of this model lies in recognizing that in the knowledge economy era, the dynamic relationships among universities, industry, and government serve as the key driving force for innovation system development. At the micro-teaching level, we have translated this concept into three core forces that drive students' innovative capability development: teaching as the foundation, research as the engine, and industry as the guiding direction. These three elements intertwine and mutually reinforce each other, forming an upward spiral of continuous innovation.

The fundamental principles of model construction include: 1) Systematic principle - viewing the cultivation process as an organic whole with coordinated efforts across all components; 2) Dynamic adaptation principle - timely adjusting cultivation content based on developments in marine science and technology; 3) Industry-education integration principle - deeply embedding industry needs throughout the talent cultivation process; 4) Personalized development principle - respecting individual student differences and providing diversified development pathways.

Regarding organizational implementation mechanisms, we have established a Teaching Steering Committee composed of college leadership, discipline leaders, and industry experts responsible for top-level design of the model; implemented a regular joint meeting system convening Teaching-Research-Industry coordination sessions twice each semester; and developed the "Implementation Plan for Innovative Practical Ability Cultivation in Marine Programs," which clearly defines objectives, content, and evaluation standards for each stage.

3. Specific Implementation Pathways of the Cultivation Model

3.1 Teaching Dimension: Restructuring Classroom Instruction through Project-Based Learning (PBL) to Solidify Innovation Foundations

The classroom serves as the primary platform, with reforms beginning from instructional methods. We have completely transformed the traditional unidirectional "teacher lectures, students listen" model by comprehensively implementing project-based learning as the core teaching reform.

Curriculum system restructuring. We first conducted a comprehensive optimization of the curriculum system, increasing the proportion of practical teaching to 34%. New practical courses such as "Marine Technology Professional Experiments" and "Frontiers in Marine Technology Lectures" were established, forming a three-tier curriculum system of "basic theory - professional core - innovative practice." Concurrently, we promptly incorporated the latest developments in marine technology, including cutting-edge content like unmanned surface vehicle observation technology and underwater Internet of Things, into the curriculum.

Implementation of project-based teaching. In core courses such as Physical Oceanography, Marine Observation Technology, and Principles and Applications of Ocean Remote Sensing, we integrate knowledge points into specific projects. Taking the "Comprehensive Hydrological Environmental Survey of a Coastal Wetland" project as an example, this 8-week project requires students to: Week 1-form teams, conduct project research and design solutions; Week 2 - learn principles and operational training for instruments like ADCP and CTD; Weeks 3-4 - conduct field observations and data collection; Weeks 5-6 - perform data processing and analysis; Week 7 - prepare research reports; Week 8 - present and defend results. Through this complete process, students not only master theoretical knowledge but also develop teamwork, project management, and practical problem-solving skills.

Experimental teaching reform. We significantly reduced the proportion of verification experiments, increasing design and comprehensive experiments to 60%[4]. A three-tier "basic-comprehensive-innovative" experimental teaching system was established. For instance, in marine remote sensing experiments, students independently design experiments on "laboratory measurement of chlorophyll-a concentration in seawater," completing the entire process from sample filtration, centrifugation, and storage to spectrophotometer use. Laboratories operate on a 24/7 open access system, allowing students to independently schedule experimental time through a reservation system.

Assessment method reform. We completely abandoned the "single exam determines grades" model, constructing a diversified evaluation system where project reports account for 30% of total assessment, teamwork for 20%, on-site operations for 25%, and presentation performance for 25%. This assessment approach emphasizes evaluating students' performance and growth during the project process rather than solely focusing on final outcomes. Simultaneously, we established an electronic portfolio system to comprehensively document students' developmental trajectories.

3.2 Research Dimension: Leveraging High-Level Research Platforms and Projects to Enhance Teaching and Ignite Innovation

The core advantage of universities lies in research. We are committed to breaking down barriers between research and teaching through the following mechanisms to transform high-quality research resources into teaching assets:

Comprehensive research mentorship system. Since 2019, we have implemented a universal undergraduate research mentorship system. Each student is assigned a research mentor starting from their second semester, responsible for academic guidance, research training, and career planning. To date, over 100 faculty members have served as research mentors, guiding undergraduates to win over 100 competition awards. Mentors conduct at least two face-to-face meetings monthly to guide students' research project participation.

Integrating research projects into teaching. We transform content from faculty-led national research projects into teaching resources. Over the past three years, content from 6 National Natural Science Foundation projects and 3 key R&D program projects has been simplified and adapted into comprehensive assignments or graduation project topics for senior undergraduates. For example, the "South China Sea Internal Wave Observation Study" project was transformed into a "Internal Wave Data Processing and Analysis" comprehensive experiment, enabling students to work with authentic research data and frontier problems.

Open access to large-scale instrument platforms. We established a large instrument sharing platform where, under faculty guidance and after systematic training and safety assessments, undergraduates can access 17 categories of large-scale equipment. The "Undergraduate Usage Management Measures for Large Instruments" implements a licensed operation system. Over three years, more than 500 undergraduate person-times have utilized advanced equipment like scanning electron microscopes and liquid chromatography-mass spectrometers, significantly stimulating research interest.

Research club development. We support students in establishing marine science and technology innovation clubs, providing faculty advisors and activity spaces. Clubs regularly organize academic salons and technical training activities, serving as important supplements to classroom instruction. The marine remote sensing club developed "Remote Sensing Monitoring of Suspended Matter Concentration in the Yellow River Estuary and Adjacent Waters Supported by Domestic Remote Sensing Software," which won second prize in the National Undergraduate Life Sciences Competition.

3.3 Industry Dimension: Deepening Industry-Education Integration to Address Real Needs and Anchor Innovation Direction

The ultimate purpose of education is to serve society. We have established strategic partnerships with 23 leading marine enterprises and research institutes, deeply integrating industry needs throughout the cultivation process through the following mechanisms:

Practical base construction. We co-established 8 "industry-university-research" integrated practical bases with enterprises. These are not simple internship reception stations but entities genuinely engaged in technical problem-solving, product development, and talent cultivation. A "work placement internship" system was implemented, where students participate in actual engineering projects during their senior year.

Industry-proposed graduation projects. Graduation project (thesis) topics are directly derived from enterprises' actual technical challenges. Over three years, 156 "industry-proposed" graduation projects have been conducted, with multiple outcomes like "Remote Sensing Monitoring of Water Transparency in Jiaozhou Bay" being adopted by enterprises. Industry engineers and university faculty form joint supervision teams, with student outcomes directly subjected to industry validation.

Industry faculty team building. We have invited numerous senior engineers and technical directors as industry mentors to offer 12 courses including "Frontiers in Marine Technology Lectures." These courses directly convey the latest technological applications, industry standards, and market dynamics to students, ensuring their knowledge structure keeps pace with industrial development[5]. Concurrently, we annually select 10 young faculty members for industry secondments to enhance engineering practical abilities.

Collaborative innovation platforms. We have established strategic cooperation agreements with enterprises to jointly apply for research projects and conduct technical problem-solving. Over three years, we have jointly undertaken 3 projects and co-published 4 papers, providing students with high-level platforms for participating in cutting-edge technology research.

4. Practical Outcomes and Reflection

After four years of practical exploration, this cultivation model has achieved significant results:

Substantial enhancement of student innovation capabilities. Between 2021-2024, student participation in technological innovation competitions increased dramatically. In competitions like "Internet Plus," "Challenge Cup," and the National Robotics and Artificial Intelligence Competition, national awards grew from 2 in 2020 to 15 in 2024 - a 7.5-fold increase. Patent applications rose from an annual average of 4 to 22.

Improved faculty teaching quality. Faculty continuously update teaching content and engage with industry practices, achieving mutual enhancement of teaching and learning. Over four years, faculty have won 3 teaching achievement awards, secured 1 national first-class course, and published 4 textbooks. Young faculty's engineering practical abilities improved significantly, with "dual-qualified" (academic and industry-experienced) faculty reaching 90%.

Enhanced social service capability. Through industry-education integration, the college's social service capacity improved markedly. Over three years, we solved 20 technical problems for enterprises, with technology transfer amounts exceeding 15 million yuan. The established marine observation data sharing platform serves over 30 organizations, generating significant social benefits.

Reflection and outlook reveal ongoing challenges in deeper implementation: First, higher demands on faculty's engineering practical abilities expose some faculty's insufficient industry experience; second, the long-term motivation mechanism for industry participation needs strengthening through mutually beneficial cooperation frameworks; third, the high costs of whole-process management require sustained funding.

Future improvements will focus on: 1) Building incentive mechanisms incorporating teaching reform outcomes into professional evaluation and performance assessment systems; 2) Deepening "dual-qualified" faculty development through industry secondment programs; 3) Exploring more institutional innovations for "university-enterprise collaborative education"[6], establishing joint management structures; 4) Actively utilizing information technologies like virtual simulation to develop virtual marine experiment platforms, overcoming high-cost, high-risk challenges in certain practical components.

5. Conclusion

Cultivating innovative marine talents constitutes a systematic project. The talent cultivation model centered on the "Teaching-Research-Industry" triple helix effectively integrates high-quality educational resources across campus and beyond, organically merging knowledge transmission, ability development, and value formation. Five years of practice demonstrate that this model solidifies innovation foundations through project-based teaching, ignites innovation engines through research feedback, and anchors innovation directions through industry-education integration, forming a closed, positive-cycle ecosystem for innovative talent cultivation.

The model's innovations include: 1) Constructing systematic implementation pathways that concretely apply triple helix theory to all talent cultivation components; 2) Establishing long-term operational mechanisms ensuring sustainable model development; 3) Achieving remarkable practical outcomes that comprehensively enhance students' innovative practical abilities.

This model's exploration and practice prove it represents an effective pathway for enhancing marine undergraduates' innovative practical abilities and serving national maritime power strategy requirements. Its concepts and methods can also inform talent cultivation reforms in other science and engineering disciplines. Moving forward, we will continue deepening model reforms, improving evaluation systems, strengthening international exchanges, and making greater contributions to cultivating more high-quality marine science and technology talents.

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