

Original Paper

Application of a Science-Education Integration Experimental Platform in Research-Oriented Teaching of Marine Technology

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Abstract

With the continuous rise in global demands for marine strategy and the in-depth advancement of new engineering education reform, the cultivation of marine technology professionals is shifting from a knowledge-transfer-oriented model toward a research- and innovation-driven paradigm. However, at the undergraduate level, current teaching practices still commonly face challenges such as the disconnection between classroom instruction and scientific research, insufficient experimental resources, and the absence of a systematic framework for fostering students' innovative capabilities. Against this backdrop, an integrated science-education experimental platform characterized by standardization, informatization, and digitalization has been introduced. This study leverages scientific research resources to reinforce teaching and replaces traditional didactic instruction with research-oriented pedagogy in core courses of marine technology. By constructing an end-to-end science-education integration model, restructuring the practical teaching system, and optimizing the evaluation mechanism of talent cultivation, this work effectively enhances students' engineering practice ability, research thinking, and innovative design competence, thereby establishing a replicable framework for experimental teaching reform. The results demonstrate that the science-education integration experimental platform exerts a significant positive impact on teaching effectiveness and offers substantial value for pedagogical innovation in marine technology education. It provides an important reference for promoting the transformation of undergraduate education in marine disciplines under the context of new engineering education in China.

Keywords

science–education integration, marine technology education, research-oriented teaching, experimental teaching platform

1 Introduction

Marine Technology is a core discipline in supporting China’s national strategy of becoming a maritime power. However, a growing mismatch has emerged between current talent cultivation systems and the rapid advancement of frontier marine technologies. With sustained progress in marine observation, marine equipment development, and remote sensing applications, undergraduate students are increasingly challenged in engineering practice, systems thinking, and innovative application capabilities (Del-Río Fernández, Toma, Carandell-Widmer M et al., 2024). Nevertheless, conventional instructional models remain largely confined to theoretical lecturing and routine laboratory exercises, offering limited opportunities for students to engage in authentic research tasks. As a result, it is difficult for students to develop the comprehensive competencies required for future marine engineering contexts during their undergraduate studies (Seroy, Airola, Rupan et al., 2025). In response to these challenges, the higher education community has proposed the concept of “science–education integration and collaborative education,” emphasizing the deep integration of scientific research and teaching, and fostering students’ cognitive development and innovative thinking through systematic training in research methodologies (Ommering & Munneke, 2025). However, in the field of marine technology education in China, science–education integration remains at an exploratory stage, and a mature and systematic framework has yet to be established. Consequently, constructing an experimental teaching system that supports new models of talent cultivation has become a widely recognized direction for reform (Macheridis, Pihl, Paulsson & Pihl, 2024).

With the accelerating global exploitation of marine resources, marine observation technologies, intelligent marine information systems, and marine engineering equipment are undergoing rapid development, driving a profound transformation in marine science and technology education (Antonio, 2026). Internationally, research-oriented learning systems are widely adopted, in which students are embedded in authentic research environments and trained through hands-on engagement in observational instrumentation, offshore surveys, and data analysis (Seroy, Airola, Rupan et al., 2025). Representative institutions such as the Scripps Institution of Oceanography and the Woods Hole Oceanographic Institution have developed mature models of integrating research and teaching, where undergraduate education places strong emphasis on participation in shipborne observation missions, enabling students to achieve academic growth through sustained training within research teams (Antonio, 2026). In addition, organizations such as CSIRO in Australia have long provided open access to research instruments for university students, allowing them to participate in real scientific projects and thereby strengthening their innovation awareness and practical research capabilities. Overall, leading countries in marine science education have established a mutually reinforcing system in which

marine engineering practice, scientific research, and education are jointly driven (Sato & Yamamoto, 2022). The key to their success lies in using scientific research outcomes to update teaching content, employing research instruments and methodologies as core educational resources, and treating real research scenarios as essential carriers for cultivating applied competence (Chen & Luo, 2026; Munandar, Hidayat, Sanjaya et al., 2025; Li, Lee, Lin, Wang, & Huang, 2025).

By contrast, although marine technology education in China has developed rapidly in recent years, the instructional system still largely follows traditional discipline-based teaching models and exhibits structural limitations (Gradone, Schofield, Glenn et al., 2025). On the one hand, curriculum content lags behind scientific and technological advances, and frontier technologies such as advanced optical remote sensing and intelligent sensor network deployment have not been sufficiently integrated into teaching systems (Munandar, Hidayat, Sanjaya et al., 2025). On the other hand, undergraduate students have limited access to research platforms, and most laboratory work remains confirmatory or fragmented in nature, lacking inquiry-driven experimental contexts. This restricts the translation of learning outcomes into research innovation and engineering application capabilities. In addition, the fragmentation of teaching resources further constrains competency development (Sharma, 2021; Hong, & Thi, 2026). Expensive research equipment is often subject to strict management, limiting undergraduate access, while offshore survey platforms are even less available for general teaching purposes. Moreover, theoretical and experimental teaching remain physically and structurally separated, preventing laboratory courses from covering the full research workflow. As a result, students struggle to understand the intrinsic logic linking observation system design and data acquisition, and interdisciplinary integration abilities remain underdeveloped (Yang, Xue, Fu et al., 2024; Ma, Guo, Zhang et al., 2020; Cano, Lluch, Grané, & Remesal, 2023). Compared with mature international practices, the depth and intensity of research-enabled teaching at the undergraduate level in China remain insufficient (Tian, 2025).

Taken together, whether from the perspective of educational policy, industry demand, or technological development trends, there is a clear consensus: marine technology education must transition from knowledge transmission to research-driven talent cultivation, from experimental verification to authentic task-based learning, and from fragmented courses to an integrated teaching system covering the entire research process (Suranta, Simanjuntak, & Sijabat, 2025). Against this background, this study is based on a self-developed science–education integration experimental platform established by the School of Ocean Technology Science at Qilu University of Technology. It aims to support the development of student competencies through an innovative experimental system, promote pedagogical reform through curriculum restructuring, and enhance learning depth through research-task-driven instruction, thereby addressing key challenges in marine technology education in China and establishing a sustainable, end-to-end, and robust research-oriented teaching model that advances the overall transformation of the talent cultivation system.

2. Overall Design of Teaching Reform

Grounded in the requirements of new engineering education and driven by China's maritime power strategy, this study proposes a teaching reform framework centered on a science–education integration experimental platform. The proposed framework takes competency development as its guiding thread, situates learning within authentic research tasks, is supported by a whole-process assessment mechanism, and is institutionally sustained through multi-stakeholder participation. In this way, it establishes an educational structure characterized by “research-led orientation, teaching-driven implementation, practice-based deepening, and innovation-oriented development,” thereby effecting a fundamental shift in talent cultivation from knowledge transmission to competency development.

2.1 Reform Concept: Reconstructing a Research-Driven Logic of Talent Cultivation

Conventional practical teaching systems are largely oriented toward procedural “operations,” whereas marine technology education under emerging disciplinary demands requires the development of higher-order cognitive abilities that progress from understanding, design, validation, to innovation. In this context, this study proposes a pedagogical concept centered on the internalization of research thinking. Experiments are no longer treated merely as extensions of theoretical instruction; instead, students are engaged in the full cycle of scientific inquiry, including problem identification, experimental design, comparative analysis of solutions, and scientific interpretation. In this way, the research process itself is embedded as an integral component of teaching activities.

The science–education integration experimental platform not only provides necessary infrastructure but also establishes a collaborative mechanism for joint inquiry between instructors and students. Within this framework, students learn methodologies, grasp underlying principles, and develop cognitive frameworks through engagement in authentic research tasks. Consequently, teaching content is no longer passively dependent on scientific advancement; rather, it is continuously updated through research outputs and synchronously enhanced alongside technological development, ensuring alignment between student learning and the evolving scientific frontier.

2.2 Instructional System Design: Full Integration of Research and Curriculum

To achieve competency-oriented learning outcomes, the instructional system is restructured in an integrative manner. Course design is no longer organized around discrete chapters but is instead driven by research questions, with project-based tasks serving as the connective framework between theory and practice. The curriculum is organized into a three-stage progression: “knowledge acquisition–research integration–competency breakthrough.”

In implementation, instructional activities are explicitly aligned with the research workflow. Starting from field observation requirements, students proceed through problem decomposition, instrument selection, methodological design, sample collection, data processing, report writing, and final defense. This design ensures that students participate in the complete operational logic of marine observation systems. Each learning activity is grounded in authentic scientific and engineering contexts rather than

simulated exercises, enabling students to naturally develop scientific reasoning and engineering thinking within applied scenarios.

2.3 Reform of Teaching Evaluation: A Process-Oriented, Evidence-Based Competency Assessment Framework

To prevent reform efforts from being constrained by traditional summative assessment systems, this study constructs a whole-process evaluation framework centered on evidence of competency development. Assessment is not limited to final examinations or laboratory reports but is instead based on a multidimensional portfolio of student performance evidence. This portfolio includes classroom participation and discussion quality, design rationales, data collection rigor, analytical capability, and effectiveness of research presentations. Accordingly, the evaluation paradigm shifts from “correctness of results” to an emphasis on explainability, innovation capacity, and reflective thinking.

This transformation ensures that students’ learning orientation shifts from grade-driven motivation to competency-oriented development. The mechanism further recognizes exploratory behavior, cognitive conflict, and methodological innovation throughout the learning process, thereby encouraging meaningful engagement in both learning and scientific inquiry.

3. Construction of the Science–Education Integration Experimental Platform and Its Teaching Operation Mechanism

The essence of science–education integration lies not in the simple conversion of research outcomes into course materials, but in the creation of a comprehensive instructional ecosystem capable of supporting learning throughout the entire research process. Accordingly, the science–education integration experimental platform proposed in this project is not a laboratory with a single function, but an integrated innovation platform that combines hardware facilities, data resources, software support, and research tasks. Its development follows the principles of research-led orientation, educational engagement, competency implementation, and continuous upgrading, forming a complete chain from foundational capacity support to the cultivation of innovative abilities, and thereby providing stable and reliable systemic support for research-oriented teaching in marine technology education.

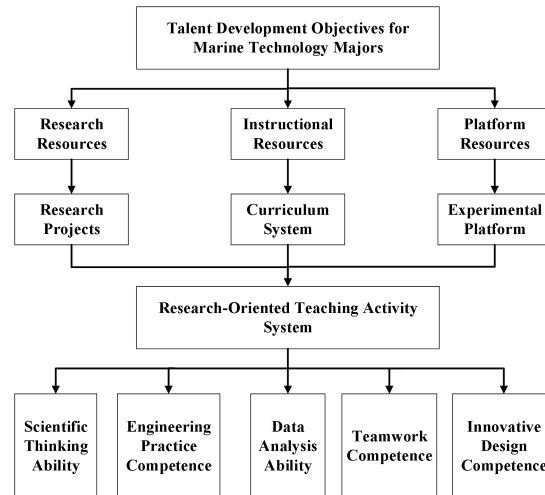


Figure 1. Overall Architecture of the Science–Education Integration Experimental Platform

As shown in Figure 1, the science–education integration experimental platform constructed in this study is designed to support the cultivation of innovative talent in marine technology. By integrating research resources, teaching resources, and experimental platform resources, it enables the deep integration of research projects, curriculum systems, and experimental teaching, ultimately forming a research-oriented teaching framework guided by competency development.

3.1 Resource Composition System: Integrated Support of Hardware, Software, and Data

The construction of the platform enables the deep integration of marine observation equipment with digital and information-based resources. At the hardware level, the platform integrates existing ocean sensing instruments from both the university and partner research institutions, including underwater optical measurement systems, satellite remote sensing radiometers, and supporting sampling and calibration equipment. This provides students with authentic, end-to-end experience in operating marine observation instruments. The learning environment is thus extended from shore-based laboratories to shipborne observation scenarios, bringing training conditions closer to real engineering practice.

At the software and data level, the platform is equipped with satellite remote sensing data processing tools, observation data correction algorithms, and self-developed models for data quality analysis. In addition, it provides students with open access to long-term observational datasets from representative sea areas, enabling scientific analysis and model inversion based on real-world data. This effectively addresses the long-standing limitation in conventional teaching, where insufficient data availability constrains in-depth research activities.

Furthermore, a traceable data archiving and management system has been established, allowing data generated during teaching activities to be incorporated into the broader research data framework, thereby supporting long-term accumulation for continued scientific inquiry. In this way, student outputs

are no longer confined to course-based exercises but may contribute to research publications and technical reports, fostering a stronger sense of research contribution.

3.2 Research Task Embedding Mechanism: Problem-Driven Deep Learning

Through the embedding of research tasks, the science–education integration platform places students in authentic problem-solving contexts. Teaching is no longer centered on instructor-led explanation but follows a structured pathway of “real-world demand → problem identification → solution design → experimental implementation → result validation.” Core teaching tasks are derived from faculty research projects, including marine ecological remote sensing, water quality change monitoring, and underwater optical signal inversion, ensuring that student learning is grounded in authentic scientific inquiry.

During task execution, students are required to conduct literature reviews, analyze technical approaches, select parameters, and validate datasets, thereby gaining a learning experience comparable to that of early-stage researchers. This platform-enabled deep learning environment significantly enhances learning quality, encouraging students to integrate interdisciplinary knowledge and construct comprehensive solutions, ultimately achieving the transition from knowledge acquisition to knowledge application.

3.3 Platform Operation Mechanism: Multi-Stakeholder Collaborative Education

To ensure sustainable platform operation, a tripartite collaborative mechanism involving faculty research teams, undergraduate teaching teams, and student research groups has been established. Research teams are responsible for introducing scientific tasks and providing technical guidance, teaching teams focus on structured instructional design, and student research groups undertake exploratory implementation and presentation of outcomes. This arrangement transforms the relationship between research and teaching from a linear top-down transfer model into an open and interactive knowledge circulation system.

In addition, a tutorial-based supervision system with small-group instruction is adopted, enabling closer mentoring relationships and more immediate feedback. This significantly enhances students’ self-directed learning ability and teamwork competence. The platform also explores collaborative partnerships with external research institutions, allowing students to access more advanced research environments and thereby broaden their practical experience and scientific horizons.

3.4 Safety and Quality Management System: Data-Driven Assurance of Teaching Effectiveness

A high-quality research–teaching integration platform must be supported by a rigorous safety management and quality control system. In this study, digital management technologies are employed to enable real-time monitoring of experimental processes. The system tracks and audits instrument usage records, data acquisition quality, and compliance with operational procedures, thereby ensuring the professionalism, standardization, and traceability of integrated teaching and research activities at the institutional level. The introduction of this digital system not only reduces administrative and instructional management costs but also significantly improves laboratory operational efficiency.

4. Analysis of Teaching Practice and Competency Development

To comprehensively examine the implementation effects of the science–education integration experimental platform in research-oriented teaching for marine technology, this study selected *Marine Observation Technology* and *Introduction to Remote Sensing* as the first round of pilot courses. In these courses, instructional content, research tasks, and the experimental platform were deeply integrated to create a learning environment grounded in authentic research practice. By conducting both cross-sectional and longitudinal comparisons of students' learning performance, competency development, and feedback data before and after the reform, this study systematically evaluates the effectiveness of the teaching reform in enhancing students' practical ability, research capacity, and overall competence.

4.1 Overview of Teaching Practice Implementation

In the implementation of teaching practice, the curriculum was organized around research task-driven instruction. Taking marine optical sensing applications as an example, instructors selected representative problems from ongoing research projects as the guiding thread of classroom learning, such as how to retrieve suspended particulate matter concentration in seawater using ocean color remote sensing and how to design an observation system to improve the inversion accuracy of Rrs₅₅₅ in turbid waters. Students independently conducted literature reviews, formulated hypotheses and solutions based on task requirements, and subsequently carried out experimental validation using spectrometers, remote sensing data processing software, and in-situ data samples provided by the platform. The final outcomes were presented in the form of research reports.

In terms of instructional organization, a group-based collaborative model was adopted. Each group addressed the same core task but explored different technical approaches, thereby establishing a comparative solution mechanism that encouraged multi-perspective thinking and in-depth discussion. Meanwhile, instructors acted as research mentors, providing technical guidance, logical refinement, and innovation-oriented direction, ensuring that the learning process aligned with authentic research logic and evolved through iterative problem-solving.

Experimental teaching was further extended beyond the classroom to field observation and virtual simulation. Students participated in coastal observation training organized by the university, where they learned sensor deployment, sample collection, on-site calibration, and error control methods. In scenarios where field conditions were constrained, a virtual simulation system was used to model deep-sea environments, ensuring continuity of observational training. This multi-scenario experimental system effectively strengthened students' adaptability to complex marine environments.

4.2 Quantitative Analysis of Competency Development

To objectively evaluate the effectiveness of the reform, this study conducted a pre–post comparative assessment across five dimensions: data processing capability, system design capability, research literacy, innovation awareness, and teamwork competence, involving a total of 66 student instances. The results are summarized as follows:

Table 1. Students' Ability Enhancement before and after the Reform

Competency Indicator	Pre-reform reaching level)	(% satisfactory	Post-reform reaching above)	(% good or Improvement
Data processing and analysis ability	41.3%		87.6%	↑46.3%
Experimental system design capability	28.5%		82.9%	↑54.4%
Scientific problem analysis ability	33.8%		85.4%	↑51.6%
Innovation awareness and solution design capability	25.6%		79.6%	↑54.0%
Teamwork and communication ability	52.4%		88.1%	↑35.7%

The data indicate that the improvement brought about by the reform is not localized but reflects a comprehensive enhancement of student competencies. In particular, significant gains in system design and scientific thinking suggest a qualitative shift in students' learning—from “knowing how to do” to “knowing how to think, explain, and innovate.”

4.3 Representative Case Study

In the course Marine Observation Technology, one student group addressed the issue of high inversion error in coastal turbid waters. They proposed a multi-band synthetic enhancement algorithm as an alternative to single-band fitting methods. Experimental validation showed that under turbidity conditions exceeding 10 NTU, the proposed method reduced inversion error by approximately 17%. This outcome not only received an excellent rating for the course project but was also incorporated into subsequent research work by the teaching team for further development.

This case demonstrates that students were not only able to master data processing techniques, but also capable of proposing scientifically grounded improvements and verifying their feasibility through experimentation, thereby exhibiting preliminary research-oriented thinking.

4.4 Student Feedback and Instructor Evaluation

Questionnaire surveys and interviews were conducted to collect student feedback on the course experience, while instructors provided a complementary evaluation of classroom performance and learning outcomes.

From the student perspective, the results indicate a strong positive response to the reformed instructional model. Over 90% of students reported a significant increase in research interest and career confidence; more than 85% stated that they were able to experience what “real scientific research”

looks like within the course; and over 80% actively applied for undergraduate innovation programs or participated in faculty-led research projects. Interview data further revealed notable shifts in students' learning cognition. Many students reported, for the first time, an understanding that "only through continuous trial and error can scientific problems be properly addressed," and that "data are not merely numbers, but representations of what is happening in the ocean." These reflections indicate a clear transition from passive learning to active exploration.

From the instructor perspective, students demonstrated significantly stronger initiative and learning responsibility. Classroom discussions became more active, with a marked increase in student questioning and engagement. Laboratory reports also showed a clear trend toward research-oriented structure and standardized academic formatting. More importantly, some student outputs have reached a level suitable for potential publication, providing concrete evidence of effective teaching–research integration.

Instructors further identified several key outcomes of the reform: the alignment between instructional depth and research depth has been substantially strengthened; teaching activities are more closely connected to engineering and scientific practice; and student competency development shows sustained and progressive improvement. Overall, these findings suggest that the science–education integration experimental platform has become a critical driver for improving teaching quality and advancing research-oriented talent cultivation.

5. Reflections on the Reform and Its Broader Applicability

The application of the science–education integration experimental platform in research-oriented teaching for marine technology has yielded encouraging preliminary outcomes. However, several issues that warrant further consideration emerged during the implementation process. Educational reform is inherently a process of continuous refinement and dynamic adjustment. In particular, within this emerging model of deeply integrating research resources into undergraduate education, important questions remain regarding how to balance instructional objectives with research goals, how to maximize the effectiveness of resource allocation, and how to establish a sustainable long-term operational mechanism.

Addressing these challenges will require ongoing exploration and improvement in future practice. Therefore, a systematic reflection on the implementation process, together with an analysis of the platform's potential for broader adoption, is essential not only for advancing teaching reform in marine technology programs but also for providing valuable insights for curriculum innovation and talent cultivation in related engineering disciplines.

5.1 Practical Challenges in Science–Education Integration Teaching Reform

Although the concept of science–education integration has become an important direction in contemporary higher education reform, structural tensions remain between research and teaching in actual implementation.

First, there is an inherent divergence between research tasks and undergraduate teaching objectives. Research activities emphasize originality, exploration, and uncertainty, and their processes are often characterized by a high degree of variability. Undergraduate teaching, by contrast, places greater emphasis on the integrity of the knowledge system and the controllability of the learning process. Accordingly, a key issue in instructional design is how to select research tasks appropriate for undergraduate participation and how to ensure that teaching objectives are achieved while preserving the exploratory value of research. At the early stage of project implementation, some instructors tended to introduce research topics directly into the classroom in the hope that students could participate in the complete research process. Practice, however, showed that for lower-year students, limited disciplinary knowledge and insufficient research foundations made overly complex research tasks burdensome and, in some cases, reduced learning motivation. In response, the project gradually adopted a strategy of tiered task design, breaking complex research tasks into multiple instructional modules so that students could carry out exploratory work within their current capability range while progressively deepening their engagement in research.

Second, the opening of high-level research resources to undergraduate teaching remains constrained in practice. Marine observation equipment is typically expensive, difficult to maintain, and subject to demanding operational conditions. For example, marine spectral measurement systems, underwater observation devices, and remote sensing calibration instruments all require specialized technical support for operation and maintenance. How to increase undergraduate participation while ensuring the safe and reliable operation of such equipment remains a long-term challenge in platform construction.

In addition, research-oriented teaching places higher demands on instructors. Traditional classroom teaching relies primarily on the transmission of course knowledge, whereas science–education integration requires instructors to possess not only subject expertise but also research organization, project management, and mentoring capabilities. Instructors must be able to guide students in identifying problems, analyzing them, and developing solutions. Under these circumstances, the cultivation of a high-level “double-qualified” teaching team has become a fundamental prerequisite for advancing science–education integration.

5.2 Lessons Learned from the Construction of the Science–Education Integration Experimental Platform

Through the implementation of this project, a set of platform-building experiences suitable for research-oriented teaching in marine technology has gradually emerged.

First, the platform adheres to the principle of integrated development of research resources and teaching resources. Traditional laboratories often exhibit a separation between “teaching laboratories” and “research laboratories,” resulting in duplicated construction and low utilization efficiency. By coordinating experimental equipment, data resources, and research projects, this project enabled the sharing of teaching and research resources and improved the overall operational efficiency of the platform.

Second, the platform is driven by authentic research questions. Unlike conventional case-based instruction, this project emphasizes problems derived from real research needs. For instance, in the marine remote sensing module, students worked with data generated from faculty-led research projects; in the marine observation system design module, the problems they addressed originated from actual engineering scenarios. Such authenticity not only strengthened students' interest in learning but also enhanced their capacity for knowledge transfer.

Third, the project adheres to the principle of whole-process competency development. Implementation showed that student growth did not result from any single experimental activity, but rather from the combined effects of problem identification, solution design, experimental implementation, data analysis, and presentation of outcomes. Research-oriented teaching should therefore build a complete competency-development chain rather than focusing on isolated instructional links.

Finally, reform of the evaluation system was advanced in parallel with teaching reform. Traditional assessment methods often fail to accurately reflect the development of students' research and innovation capabilities. This project gradually established a comprehensive evaluation mechanism that combines process-based assessment with outcome-based assessment, ensuring that students' exploratory efforts, teamwork, and research engagement during learning are appropriately recognized and thereby effectively stimulating learning motivation.

5.3 Value for Broader Application

From the perspective of talent cultivation, the science–education integration experimental platform constructed in this project breaks through the limitations of traditional experimental teaching and enables the effective transformation of research resources into teaching resources, thereby providing a new pathway for cultivating marine science and technology talent with innovation capacity and practical competence.

With the continued advancement of China's maritime power strategy and the new engineering education initiative, future marine technology professionals will need not only disciplinary knowledge but also the ability to solve complex engineering problems, collaborate across disciplines, and engage in technological innovation. The research-oriented teaching system developed in this study is well aligned with these requirements and is therefore of considerable value for improving the quality of talent cultivation in marine technology.

From the perspective of program development, the operational model formed in this project—"platform support, research-driven instruction, teaching integration, and competency enhancement"—has strong potential for replication. Although the study focuses on marine technology, its core principles are equally applicable to other practice-oriented disciplines such as marine science, environmental science, surveying and mapping engineering, and remote sensing science and technology. The model therefore has substantial cross-disciplinary application potential.

From the perspective of teaching reform, this project explores a new pathway for the deep integration of research resources into undergraduate education. Compared with traditional experimental teaching,

this model places greater emphasis on the central role of students and the cultivation of research-oriented thinking, making it more consistent with the requirements of high-quality higher education development in the new era. The instructional organization model, resource-sharing mechanism, and evaluation reform experience developed in this project may serve as a useful reference for advancing science–education integration reform in universities.

From the perspective of platform construction, the digital and information-based experimental platform developed in this study provides a practical foundation for future smart laboratory development. With the advancement of artificial intelligence, big data, and digital twin technologies, experimental teaching in marine technology will gradually move toward intelligentization. The operating mechanisms and management experience accumulated in this project may offer valuable insight for subsequent construction of smart experimental platforms.

5.4 Prospects for Future Development

Building on the current foundation, this study will continue to deepen the reform of science–education integration in future work. On the one hand, the platform will be further opened to expand access to additional research projects and advanced observation equipment, thereby enriching resources for research-oriented teaching. On the other hand, greater emphasis will be placed on the integrated application of virtual simulation, artificial intelligence, and experimental teaching, with the aim of developing a new model of laboratory instruction that integrates online and offline learning.

At the same time, the project will further improve the tiered research training mechanism and establish a developmental pathway for research competence across the different stages of undergraduate education. This will create an organic connection among research-oriented course learning, undergraduate innovation and entrepreneurship training programs, and participation in faculty research projects, thereby gradually forming an innovation-oriented talent cultivation system with distinctive marine technology characteristics.

Overall, the science–education integration experimental platform is not merely a mode of laboratory resource construction; it also represents an innovation in educational philosophy aimed at cultivating future marine science and technology talent. As reform practices continue to deepen, its role in improving talent cultivation quality, promoting the transformation of research outcomes, and advancing the modernization of teaching and learning will become increasingly evident, providing sustained momentum for the high-quality development of marine technology education in the new era.

6. Conclusion

With the continuous advancement of the new engineering education initiative and China's maritime power strategy, traditional teaching models in marine technology programs have gradually revealed certain limitations in talent cultivation, including insufficient utilization of practical teaching resources, weak integration between scientific research and classroom instruction, and inadequate development of students' innovation capabilities. Consequently, how to fully leverage the research advantages of

universities, promote the transformation of research outcomes into instructional resources, and construct a research-oriented teaching system that meets the demands of cultivating marine technology professionals in the new era has become an important issue in educational reform.

This study, supported by the university-level teaching research project of Qilu University of Technology titled "Application of a Science–Education Integration Experimental Platform in Research-Oriented Teaching of Marine Technology," has developed a research-oriented teaching system centered on the science–education integration experimental platform to meet the needs of cultivating innovative talents in marine technology. By integrating multiple resources including research instruments, scientific data, research projects, and faculty expertise, this study has established a teaching operation mechanism characterized by "platform support, research-driven instruction, teaching integration, and competency enhancement," achieving a deep integration of research and teaching resources. On this basis, taking core courses such as Marine Observation Technology as examples, authentic research problems, cases, and tasks have been introduced throughout the instructional process, guiding students to engage in independent exploration and collaborative learning in the stages of scientific problem identification, experimental design, data acquisition and analysis, and presentation and communication of results, thereby gradually forming a student-centered, competency-oriented research-based teaching model.

Practical results indicate that the science–education integration experimental platform effectively overcomes the limitations of traditional laboratory teaching, such as the predominance of confirmatory experiments and insufficient student engagement in research. It significantly enhances students' scientific reasoning ability, engineering practice capability, data analysis skills, and innovative design competence. Through exposure to authentic research scenarios, students not only gain a deeper understanding of the course content but also develop scientific inquiry awareness and an innovative spirit while solving real-world problems, achieving an organic integration of knowledge acquisition, competency development, and value shaping. Meanwhile, the platform promotes open sharing of research resources, improves the utilization efficiency of experimental equipment, strengthens the collaborative education capacity between research teams and teaching teams, and fosters a virtuous cycle in which teaching benefits research and research enriches teaching.

The innovations of this study are mainly reflected in three aspects: First, it constructs a science–education integration experimental platform model characterized by tripartite collaboration among research teams, teaching teams, and student research groups, achieving systematic integration of research and teaching resources. Second, it establishes a research-oriented teaching operation mechanism driven by authentic research tasks, embedding the entire research process into course instruction and achieving deep alignment between knowledge transmission and competency development. Third, it develops a whole-process assessment framework oriented toward innovation capability cultivation, shifting the focus of teaching evaluation from outcome-oriented to competency-oriented assessment, thereby providing new approaches and methodologies for practical

teaching reform in marine technology programs.

From the perspective of broader application, the experience gained in constructing the science–education integration experimental platform and the research-oriented teaching model developed in this study are not limited to marine technology programs but can also serve as a reference for other practice-oriented disciplines such as marine science, remote sensing science and technology, environmental science and engineering, and related fields. Particularly in the current context of higher education institutions promoting science–education integration, new engineering education, and innovative talent cultivation, the educational reform pathways explored in this study possess strong replicability and transferability, offering positive implications for transforming research advantages into talent cultivation strengths and improving the quality of undergraduate education.

In the future, with the rapid development of emerging technologies such as artificial intelligence, big data analytics, digital twins, and virtual simulation, experimental teaching in marine technology will continue to evolve toward digitization, intelligentization, and openness. Building on the current foundation, this study will further refine the construction mechanism of the science–education integration experimental platform, deepen the integration between research projects and the curriculum system, explore multi-tiered research training systems and personalized talent cultivation models, and continuously enhance students' innovative practice ability and research literacy, thereby providing more solid support for cultivating high-quality marine technology professionals capable of meeting the demands of marine science and technology innovation.

In summary, the construction and application of the science–education integration experimental platform not only promotes the innovative development of research-oriented teaching models in marine technology programs but also provides valuable exploration for research-based education and innovative talent cultivation in higher education in the new era. As reform practices continue to deepen, its role in improving talent cultivation quality, advancing educational reform, and serving China's maritime power strategy will become increasingly significant.

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