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COLLABORATIVE INNOVATION MODELS FOR APPLICATION-ORIENTED MARITIME UNDERGRADUATE COLLEGES UNDER THE BACKGROUND OF BUILDING A MARITIME POWER

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Abstract: Building a maritime power is a talent problem before it is a technology problem, and application-oriented maritime undergraduate colleges sit where the two meet. Their inherited teaching models, though, were designed for a shipping industry that no longer exists, and the distance between what they produce and what the blue economy needs has widened under digital transformation. This paper asks what collaborative innovation actually looks like inside such institutions, and whether the multi-stakeholder arrangements now promoted in Chinese policy close that distance. The study is qualitative. It works through the Triple Helix and Quadruple Helix literatures, reads the relevant policy texts, and then examines three Chinese institutions in detail (Jimei University, Dalian Maritime University, and Jiangsu University of Science and Technology). Four arrangements recur across the cases: government-university-industry-research synergies, industry-education integration platforms, project-based training mechanisms, and ecosystems built around digital intelligence. Where these are in place, graduates match employer requirements more closely and maritime technologies reach commercial use faster. Cross-sector partnership needs institutionalizing rather than improvising, and digital infrastructure should be treated as shared equipment rather than as a departmental purchase. Without both, maritime higher education will go on describing itself as a servant of national strategy while lagging behind it.
Keywords: Maritime power; Application-oriented universities; Collaborative innovation; Industry-education integration; Quadruple Helix model; Blue economy

1 INTRODUCTION

Building a maritime power is a national agenda with several moving parts at once: marine economic strength, technological capability, and the ecological condition of the sea itself. Talent sits underneath all three. So does applied research of the kind that reaches industry rather than only journals. Application-oriented maritime undergraduate colleges are where national strategy is supposed to become curriculum, laboratory work, and eventually a person who can do a job [1]. Their remit differs from that of research-intensive universities. They are expected to stay close to the industries around them, close enough that what is taught, who teaches it, and what gets researched all shift when the regional maritime economy shifts.

The mandate is clear enough. Meeting it is another matter. Marine technology has been moving quickly, driven by digitalization, decarbonization, and smart shipping, and institutional adaptation has not kept pace. Graduates arrive in the labor market holding skills that employers no longer rank highly, while those same employers describe vacancies they cannot fill. This is the familiar theory-practice gap, and it slows industrial upgrading [2]. Institutional barriers make it worse. Resources, people, and knowledge do not move easily between a university and a shipping company. Many faculty members have never worked in the industry they teach about. Firms, for their part, hesitate: the returns on an educational partnership are hard to forecast, and the paperwork is not.

Collaborative innovation is the usual answer offered to this cluster of problems, and it is the right one, provided the term is not emptied of meaning. The point is not knowledge transfer in a straight line from university to firm. It is co-creation, shared governance, and value that accrues to more than one party. In maritime settings this means pulling four things into a single arrangement: policy direction from government, educational capacity from universities, demand signals from industry, and environmental and social expectations from the wider public. Triple Helix theory and its Quadruple Helix extension supply the vocabulary for this [3-4]. Both frameworks make the same underlying claim. Innovation is organizational and social work, not only technical work, and it requires people to keep showing up across sectoral boundaries.

What follows is an attempt to take apart the collaborative innovation models now appearing in China's application-oriented maritime higher education sector. Four tasks organize the paper. The first is theoretical: to set out what multi-helix thinking offers applied maritime education. The second is contextual, covering the policy environment and the obstacles institutions actually run into. Third, five models are described in enough detail that they could be recognized, or attempted, elsewhere. Fourth, those models are tested against three cases. The contribution is meant to be double, offering something to the literature on higher education reform and something usable by the people who run

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these universities and the agencies that fund them. Behind all of it lies a simple claim: these colleges can stop being passive service providers and start acting as engines of maritime development, regionally and then nationally.

Some context on the industry is necessary. Shipping is in the middle of a transformation it did not choose. The International Maritime Organization has committed the sector to halving greenhouse gas emissions by 2050 against a 2008 baseline, a target that has already redirected investment toward alternative propulsion and more efficient hull and machinery design [5]. At the same time, artificial intelligence, autonomous systems, blockchain, and connected sensors are changing how ports are run and how ships are navigated. For maritime education the two trends arrive together, and they carry the same consequence: the competence profile employers want now extends well past seamanship and classical marine engineering.

For China the stakes are higher than for most. The country handles more port throughput than any other, operates a large and growing commercial and research fleet, and draws a meaningful share of national output from the sea, 7.8% of GDP in 2024, with offshore wind, deep-sea mining, and marine biotechnology expected to push that figure up [1]. The constraint is people. Too few professionals can work across the boundary where technology, sustainability, and international governance meet, and that boundary is precisely where the new maritime economy operates. Application-oriented maritime colleges supply most of this workforce. Reform of those colleges is therefore not an internal academic matter.

A word on how the paper was assembled, since the claims rest on it. The study is qualitative and interpretive, and it draws on three kinds of material. The first is theoretical: the Triple Helix and Quadruple Helix literatures, read for what they do and do not explain about applied maritime education. The second is documentary, covering national and provincial policy issued between 2015 and 2026, among them the Education Power Building Plan (2024-2035) and the 2025 Blue Book of Marine Economy, together with the institutions' own published accounts of what they have built. The third is secondary empirical work by Chinese researchers on industry-education integration, much of it published in Chinese and little read outside the mainland. I have measured nothing. What a design of this kind can support is an account of what these arrangements look like from the inside and where they tend to give way, which is a different ambition from demonstrating that they work.

Three institutions were selected, purposively rather than representatively. Jimei University, Dalian Maritime University, and Jiangsu University of Science and Technology were chosen because each is routinely cited within China as a reference case, because each has taken a visibly different route toward the same objective, and, less nobly, because each has documented what it did in enough detail to be analyzed at all. Plenty of institutions doing interesting work publish almost nothing about it. The three differ in institutional age, in regional industrial context, and in whether the dominant partner is a single state-owned enterprise or a cluster of smaller firms, which gives the comparison something to work with. It also builds in a bias worth naming at the start: these are success stories, chosen partly because they are success stories, and the paper consequently says more about what can work than about how often it does.

2 THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 Triple Helix Theory and Its Evolution

It is worth going back to what Etzkowitz and Leydesdorff were originally claiming, since repetition has worn the edges off it. Innovation, on their account, does not start inside one institutional sphere and then travel outward. It comes out of recursive traffic among universities, industry, and government, each sphere intermittently picking up work that used to belong to one of the others [3]. A university operating that way is not merely a teaching body any longer; it holds a stake in economic outcomes and behaves accordingly. Chinese maritime education went through the sequence in a fairly standard order. Technology transfer offices came first, most of them in the late 1990s. Incubators followed. Joint laboratories with shipping lines and port authorities arrived later, and in several institutions are still being built. Whether the sequence produced much is a separate question, and the answer varies by province. What the model leaves out, though, is settled. Zhou and Ge state the objection as directly as anyone: civil society does not appear in the account, and neither does the physical environment in which innovation happens [6]. Elsewhere that omission can be lived with. Not here. Environmental performance and the condition of coastal communities are not by-products of maritime innovation; a good deal of the time they are the thing being innovated about.

Nor did the original formulation foresee how far the boundaries would move in maritime settings. Teaching, research, and commercial activity have not simply blurred; in a few institutions they are no longer separable even for accounting purposes. Science parks and transfer offices give Chinese universities a formal route from a marine research finding to something a firm will pay for, and on paper the route exists everywhere. How much traffic it carries depends almost entirely on the address. Shanghai, Qingdao, Dalian: universities in those three cities sit inside maritime industrial clusters, and proximity does daily work that no policy instrument reproduces. An inland institution with research of equal quality does not have that, and institutional determination does not shorten a seven-hour train journey. Geography is not background in Triple Helix interactions, then. It fixes the boundary of what can be attempted at all, which is the stronger argument for treating regional innovation systems as objects of study rather than as scenery [7].

2.2 Quadruple Helix Model and Innovation Ecosystems

Where the first model stopped, the Quadruple Helix adds a strand that Carayannis and Campbell gloss as civil society, media, and publics organized around culture [4]. They do not treat the addition as decoration. For them it is the

condition on which Mode 3 innovation depends, with its smart specialization and its insistence that co-creation be driven by users and not by producers. Translated into maritime terms the fourth helix stops being abstract. It is the people who live on the coast, the environmental NGOs, and a general public whose expectations about ocean governance now decide what counts as an acceptable ship or an acceptable port expansion. Song and Wang take the point further and put application-oriented universities at the center of such ecosystems, as the node the other three helices run through [8]; Wang and Fang reach much the same conclusion from the knowledge-management side [9]. The analytical shift is worth stating plainly, because it changes what one would go and measure. Attention moves off the individual partnership and onto network effects, and value gets read off the density of connections rather than off any single bilateral relationship. That is harder to count. It is probably why so few people count it.

Few sectors fit the framework this well. The externalities are large, they are visible, and public tolerance operates as a working constraint rather than a reputational one. Port expansion displaces people. Offshore energy projects move the fish and change who is allowed to go after them. Coastal communities therefore hold a claim, and a defensible one, to some say in how maritime innovation proceeds; whatever its imperfections, the Quadruple Helix at least gives that claim somewhere to be registered inside research and education agendas instead of at a public hearing eighteen months later. What the institution gets back for the trouble is legitimacy. Legitimacy used to arrive free with the letterhead. It does not now, with environmental groups, residents' associations, and international bodies examining maritime projects a great deal more closely than they did in the 1990s [4].

2.3 Application-Oriented Universities in the Knowledge Economy

An application-oriented university is defined by its clientele rather than by its subjects. Zhang and Liu call these institutions engines of regional economic development, with curricula and research agendas pinned to whichever industrial cluster happens to sit on the doorstep [10]. In maritime cases the pinning has to be specific. A college ten kilometers from a shipyard should not look like a college beside a container terminal, and neither should resemble one attached to an offshore engineering base; in practice, naturally, all three often teach the same syllabus out of the same textbooks. The demand running underneath the literature is what Zhai et al. call dual excellence, meaning academic credibility and demonstrable industrial impact held at the same time, with neither conceded to the other [11]. Reasonable enough as a goal. Hard as an operating requirement. It means rewriting what faculty are for, how they are judged, and how a department is assembled, so that applied engagement is rewarded instead of being filed under service by colleagues who regard it as time taken from real work.

China has changed its mind about this institutional category remarkably fast. "Application-oriented" began as a residual term, the thing you called a university that had not managed to become research-intensive, and it is now a planning category with funding attached to it. The Education Power Building Plan (2024-2035) instructs universities to deepen their ties with priority industries, handing maritime colleges a mandate and a budget line in a single document [11]. The same document hands them exposure. Money of this kind comes with expectations about graduate employability, partnership counts, and technology transferred, every one of which has to be evidenced on an annual cycle. Anyone who has sat through such a review knows the direction of the drift. Chasing countable applied outcomes, a college asks marginally less of its students each year. Nobody decides this. It happens by increments, and the credibility the institution set out to build goes out from underneath it.

2.4 Collaborative Innovation in Higher Education

Collaboration in the sense the literature now uses has travelled a long way from the memorandum of understanding. Li and Chen examined Chinese university-industry partnerships that were functioning rather than merely signed, and the functioning ones shared three things: intellectual property arrangements settled in advance instead of deferred until there was something worth arguing over, staff holding appointments in both organizations, and curricula built jointly rather than shown to an advisory board once already finished [12]. Ji and Xu offer a measure, deliberately blunt, which is simply how much research turns into technology somebody uses [13]. For a maritime university that figure, they argue, is the most honest statement available about collaborative performance. It is also, in most cases, unflattering. The direction of travel runs away from transactional work, a consulting contract here and a guest lecture there, and toward arrangements in which both sides put resources into capability that neither of them owns. Digital technology accelerated the shift, though less by contributing anything conceptual than by making shared data environments, remote collaboration, and virtual training facilities cheap enough to stop being remarkable [5].

3 POLICY CONTEXT AND CURRENT CHALLENGES

3.1 China's Maritime Power Strategy and Blue Economy

Four things are gathered under the maritime power strategy that are, administratively, handled by different ministries: the marine economy, technological self-reliance, ecological civilization, and China's position in global maritime governance. On the first of them the Blue Book of Marine Economy documents a real change of basis, from growth produced by extracting resources toward growth expected from innovation [1], and links it to the policy vocabulary of new quality productive forces [2]. Any change of that sort assumes a workforce able to handle advanced manufacturing, digital tooling, and sustainability practice, and it assumes it rather casually. The dual carbon commitments tighten

matters further, pushing attention onto alternative fuels, vessel efficiency, and carbon accounting. That last item was not a maritime job description ten years ago. It is now advertised on recruitment sites with a salary band attached [14]. Someone has to supply these people, and the applied research alongside them. The job has gone to the application-oriented maritime colleges, which were not asked.

3.2 Application-Oriented University Reform

For several years national policy has been pushing ordinary undergraduate colleges toward an application-oriented identity, the stated reason being a structural mismatch between what higher education turns out and what employers say they need [15]. The instruments will be familiar to anyone who has sat on the relevant committees: industry advisory boards, competency-based curriculum design, more hours of practical training. It is at implementation that the picture comes apart. A number of institutions have genuinely rebuilt themselves around these requirements. Others produced the documentation. Evaluation is catching up with the difference, slowly. Publication counts no longer dominate assessment to the degree they once did, and collaboration metrics, graduate employment quality, and transfer outcomes now carry real weight [16].

Two obstacles to this reform are rarely stated plainly: the faculty, and the culture they work in. Academics in older maritime colleges were trained under a research-intensive logic and promoted under it, which means theoretical publication is what they know how to produce. Changing the evaluation criteria does not by itself change what people are able to do. Real movement requires sustained investment in development programs, building industry relationships, learning to run applied projects, acquiring a pedagogy appropriate to practice-based teaching. There is a generational dimension as well. Younger staff are often willing, sometimes eager. Senior colleagues, whose standing rests on traditional academic achievement, have less reason to be [16].

3.3 Integration of Education, Science and Technology, and Talent

Policy now insists that education, science and technology, and talent be developed as one thing rather than as three portfolios with three sets of indicators. The reasoning is that each reinforces the others and that optimizing any of them alone wastes the other two. Translated into the running of a maritime college, teaching, research, and talent cultivation have to be designed as a single process. Research ought to reach the curriculum inside a year or two rather than a decade. Students ought to be doing work that research teams would otherwise have to do themselves. And an industry partnership delivering only one of educational, technological, or recruitment value is probably not worth what it costs in administrative time, however well it photographs in the annual report. Get this right and the same money buys graduates and technology together; get it wrong and it buys neither very well.

3.4 Key Challenges in Collaborative Innovation

Favorable policy has not dissolved the difficulties, and the difficulties are tangled enough that removing one of them on its own achieves close to nothing. Begin with curriculum lag. Smart shipping and green marine engineering move faster than course approval does, so a student can graduate holding knowledge that depreciated during the degree itself. Underneath that sits the theory-practice gap, mostly an artifact of hiring: faculty are recruited on academic credentials, so whoever teaches an applied subject may never have done it [17]. Digital transformation ought to help and sometimes does, but a fair number of institutions lack the infrastructure, or the staff confidence, or the pedagogical frameworks, and stall at the demonstration stage with an expensive simulator nobody has timetabled [5]. Then the structural obstacles, which are the ones that outlast everybody: administrative rigidity, incentive systems that fail to line up across organizational boundaries, and ownership arguments that recur in every negotiation and are never settled in principle, only case by case. Faculty development meets the same wall from another direction, since an evaluation system that discounts industry service makes industrial recruits hard to attract and incumbent staff hard to persuade. None of this is susceptible to a pilot project. It takes change in institutional culture and governance, and that runs in years rather than funding cycles.

The international character of the industry adds a further layer. A maritime professional may deal with three jurisdictions, two regulatory regimes, and several languages inside a single week, and a module on maritime English does not fully prepare anyone for that. Plenty of application-oriented colleges have added international content to their programs; far fewer have an internationalization strategy worth the name. Competition for qualified people has meanwhile intensified since the pandemic, with shipping companies and the industries next door drawing from the same shallow pool, and that competition has made the distance between educational output and industry need a good deal more visible than it used to be.

Sustainability literacy is the newer gap, and the awkward one. Getting to a low-carbon blue economy will take people who understand alternative fuels and efficient design, obviously, but also the policy instruments, the economics, and the social consequences attached to them. Maritime curricula are not built to deliver that. They are organized by discipline, and sustainability is not a discipline; neither is digitalization, nor global governance. Each of them cuts across everything else. Rebuilding a program around themes instead of departments is administratively miserable, which goes a long way toward explaining why so few institutions have attempted it.

4 COLLABORATIVE INNOVATION MODELS

4.1 Government-University-Industry-Research Synergies

At base the model is a coordinated arrangement among four parties, and on paper the division of labor is clear. Government supplies direction, money, and the regulatory conditions that make collaborating a rational act rather than a charitable one. Universities supply knowledge and people. Firms supply problems worth solving, market information, and the resources applied work consumes. Research institutes, the national laboratories among them, occupy the uncomfortable middle ground between basic and applied science that neither a university department nor a corporate R&D unit covers properly. Ning et al. find measurable gains in regional marine high-tech innovation efficiency where the four are governed together instead of operating in parallel and meeting twice a year [7]. Governed is the operative word. Coordination has to be formal, which means joint steering committees, pooled funding, and performance metrics rewarding what the partnership produced rather than what each organization can enter separately in its own annual return. Informal goodwill is pleasant to work with. It does not outlive the first round of staff turnover.

4.2 Industry-Education Integration Platforms and Modern Industry Colleges

Integration platforms do something structurally different from coordination. They place the industrial partner inside the educational process rather than beside it. Modern Industry Colleges, a Chinese policy invention with no exact equivalent elsewhere, are the clearest case: semi-autonomous units governed jointly by a university and one or more major firms [13]. Curriculum development, teaching, training facilities, assessment of competence, all of it is held in common, which is harder than the word shared makes it sound, because sharing responsibility also means sharing the power to refuse. Dalian Maritime University shows what the arrangement does when it works [18]. Industrial problems reach university researchers through a defined channel; university solutions reach industrial application through another; neither depends on who happens to know whom that year. Whether any of it holds comes down to governance. Academic and commercial interests do not coincide naturally, and the rules have to protect educational quality without turning the firm's participation into philanthropy, which is a narrower path than it sounds.

Certain design features keep reappearing in the Modern Industry Colleges that function. Steering committees on which university and industry hold equal representation. Budgets pooled from several sources rather than drawn from one, which matters more than it appears to, since a single funder eventually starts behaving like an owner. Personnel rules loose enough to permit joint appointments and industry sabbaticals without wrecking somebody's promotion case. On incentives Jiangsu University of Science and Technology has gone further than most, introducing an annual salary system, letting researchers assemble their own teams, and allowing achievement transfer revenue to reach 100% for the researchers involved. Faculty motivation improved sharply. That result is not surprising; the interesting part of the case is not the result but what it implies, which is that incentive design is one of the few strong levers an institutional leader genuinely controls, rather than an implementation detail to be tidied up later by human resources [11].

4.3 Project-Based and Problem-Based Training Mechanisms

Structural reform without pedagogical reform yields a well-governed institution delivering the courses it delivered before. Project-Based and Problem-Based Learning tie coursework to problems an industry partner actually has: container flow through a particular port, a hull designed to hit a stated efficiency figure, a stretch of coastal water instrumented so somebody can finally see what is going on in it. Students work in teams. They acquire technical skill, and along the way they learn to disagree without falling out, to explain a design to a person who is not an engineer, and to decide on incomplete information. An examination detects none of those three. Jimei University runs what it calls a multi-dimensional, three-dimensional model, threading the approach through an entire program so that classroom teaching, laboratory work, and internships become one sequence rather than three unconnected experiences [19]. The faculty role moves with it. Lecturer becomes facilitator, usually working alongside an industry mentor, and often learning from the project at roughly the rate the students are, which some find uncomfortable and others consider the best thing about the arrangement.

Running this is harder than describing it. Project-based teaching needs faculty who can facilitate instead of lecture and who hold the contacts to source genuine problems; most academics have one of the two. The usual remedy is a structured sabbatical inside a maritime firm, and the evidence for it is reasonably good, for an unglamorous reason: six months in a shipping company teaches a lecturer which problems are real and which ones exist in order to be mentioned in press releases. Assessment is the harder half. Judging a project team properly needs instruments that register teamwork, communication, and inventiveness alongside whether the answer came out right, and the apparatus maritime education inherited was built to check the last of those and nothing else [13].

4.4 Digital Intelligence-Empowered Innovation Ecosystems

What digital transformation changes is the price of collaborating. Digital twins, machine learning, large-scale data analysis, and virtual reality let partners work across distance and across organizational boundaries that formerly required everybody in one building on the same morning. Chen and Li describe how digital-intelligent requirements are reshaping ship and ocean engineering programs, with simulation platforms letting students attempt operations that would be unsafe, ruinously expensive, or simply unavailable [17]. The same infrastructure moves live data between a university and a firm, which makes joint work possible on operational optimization, predictive maintenance, and

environmental monitoring. Transaction costs come down. Knowledge that was tacit becomes at least partly inspectable. And learning stops being something confined to the years when a person is formally enrolled somewhere.

Some caution is in order. Data governance questions remain unsettled, access to digital infrastructure is distributed unevenly across institutions, and a number of competencies do not transfer out of simulation at all. The judgment a deck officer exercises under pressure, the willingness to make an unpopular call, the ethics of a decision taken at three in the morning on an incomplete picture: a simulator approximates the conditions, but it cannot reproduce the stakes, and students know the difference perfectly well. Application-oriented maritime colleges should therefore treat digital tools as an addition to human-centered training rather than as a replacement for it. Onboard training, cadet programs, and time in a workshop with real machinery continue to earn their place in the timetable. Graduates need the technological fluency, and they need the other thing too, which takes longer to acquire and is much harder to teach [5].

4.5 International Cooperation and Belt and Road Maritime Education Alliance

An industry this international is not well served by collaboration that stops at the border. The Belt and Road Maritime Education Alliance connects Chinese maritime universities with institutions in partner countries and supports student and faculty exchange, joint research, curriculum alignment, and capacity building in systems where maritime education is still being assembled [20]. The benefits run inward at least as much as outward, a point usually lost in the way such arrangements are described. Students and staff encounter other regulatory environments, other technological choices, other assumptions about how a port ought to be organized, and the domestic innovation ecosystem is better for the contact. There are strategic benefits as well: people-to-people ties, the circulation of Chinese maritime standards, a larger Chinese voice in how the sector is governed. None of it survives inattention to cultural difference, genuine reciprocity, and consistency with international standards and the sustainable development agenda.

The Alliance has a second function that attracts less commentary. It is a venue for working out shared competency frameworks and education standards, which is what lets a qualification earned in one country be recognized in another. In an industry where a single crew may be assembled from five nationalities, and where inconsistent training standards convert fairly directly into safety risk, that is not a trivial contribution. Chinese maritime universities taking part in the drafting improve the mobility of their own graduates and import practices that raise standards at home. Traffic moves in both directions, and both directions are useful [20].

5 CASE STUDIES AND DISCUSSION

5.1 Jimei University: Multi-Dimensional Talent Cultivation

Jimei University describes its model as multi-dimensional and three-dimensional, a label that conveys little on its own. What does convey something is how far industry engagement has been pushed into the ordinary operations of the university instead of being parked in a partnership office with two staff and a small budget. Several Modern Industry Colleges have been established with shipping and shipbuilding firms, and curricula are designed with those partners against current standards and against what the partners expect to need in three years. Project-based learning starts in the second year and does not stop; the projects come from industry. Faculty are expected, not merely permitted, to spend substantial time inside firms through sabbaticals and joint appointments, and that expectation is what keeps the teaching current, because nothing else reliably does. Engagement reaches past industry too, into marine science outreach and environmental monitoring run with coastal communities, which is the Quadruple Helix as practice rather than as a diagram. The lesson from Jimei is that educational quality and industrial relevance do not sit at opposite ends of a see-saw, provided the commitment runs across the whole institution and lasts long enough for habits to change.

One further feature is worth noting. Jimei does not train every student the same way, on the sensible premise that students are heading for different careers and that a single track serves all of them indifferently. Three run in parallel: an Elite Class pointed at maritime administration, an Excellence Class aimed at the shipping industry itself, and a Smart Navigation Class for students going into technology development. Each keeps its own academic standards and its own industry relationships rather than sharing one generic set. Employer satisfaction has been high, and this differentiation is a substantial part of why Jimei is now spoken of as a leading institution for maritime talent cultivation in China [19].

5.2 Dalian Maritime University: Industry-Education Integration Driving Innovation

Dalian Maritime University treats its integration platforms as research infrastructure, which is a different emphasis from Jimei's. Partnerships with large state-owned maritime enterprises have produced joint research centers, transfer platforms, and talent cultivation bases, and these are operational entities rather than advisory ones: shared budgets, shared staff, research agendas written together. Conversion is the organizing priority. Moving results into industrial use is pursued through patent licensing, through spin-off formation, and through consulting work, each with a standing mechanism behind it rather than an arrangement renegotiated from scratch whenever somebody has an idea. Digital investment has added virtual simulation facilities and data-sharing infrastructure, which takes a good deal of friction out of daily work with partners several hundred kilometers away. What makes DMU worth examining is the problem of inheritance. An old maritime university carrying decades of industry relationships can turn that history into something systematic that serves teaching and technology development at once, or it can leave it where it has always sat, in the address books of professors who will retire within the decade and take it with them.

Location does part of the work, and it would be dishonest to pretend otherwise. Liaoning is a center of Chinese shipbuilding and port logistics, so faculty and practitioners meet as a matter of course, students are placed in leading firms without elaborate negotiation, and researchers reach equipment and operational data that would otherwise be entirely out of range. DMU has also used its standing as a Ministry of Transport institution to shape national maritime education policy and standards. That leaves it in an unusual dual position: it provides education, and it advises on what education ought to be. One can have reservations about the combination. What is not in doubt is that it has enlarged the university's influence over where maritime education reform in China goes next [18].

5.3 Jiangsu University of Science and Technology: Regional Service and Digital Empowerment

At Jiangsu University of Science and Technology, regional service is organized around digital capability instead of treating it as one initiative among several. The university sits inside a shipbuilding and marine equipment cluster and has set research and teaching priorities to match. Investment has gone disproportionately into digital infrastructure: smart manufacturing laboratories, digital twin platforms, AI-driven research centers, with the same equipment used for teaching and for industrial work rather than divided between the two and underused by both. The collaborative model rests on co-developing digital solutions for regional firms, faculty and students working on live industrial problems. What keeps it running is the evaluation system, which rewards them for it, so that industry collaboration and applied research count toward promotion instead of counting quietly against it. JUST is a useful case for exactly that reason. It has proximity, technical capacity, and incentives pointing the same way, and those three things usually turn up separately.

JUST has also worked at the level of the cluster rather than the individual partnership, which is the less obvious half of the story. A 3+N industry-education integration alliance with CSSC and the Jiangsu Shipbuilding Industry Association gives collaboration a standing structure, so a new project does not have to be negotiated from first principles every time one is proposed. The alliance runs student training and curriculum development, and it underwrites joint research on the problems no single shipbuilder can solve alone: green ship construction, intelligent manufacturing, digital supply chain management. Embedding itself in regional industry networks this way has given JUST collaboration pathways that outlive particular projects, and a measure of influence over how the sector's innovation ecosystem develops [11].

5.4 Comparative Analysis and Discussion

Side by side, the three cases share a floor and diverge above it. Each has moved past symbolic partnership into structural integration; each aligns programs with industrial requirements; each has found some means of getting faculty into industry and back out again. Above the floor they part company, and the parting is the instructive bit. Jimei's strength is pedagogical, built on project-based learning and on integration across the dimensions of university life. DMU trades on history and on the depth of its enterprise relationships, aiming both at research and at technology transfer. JUST concentrates on its region and on digital capability. Institutional history, geography, and deliberate strategic choice account for most of the difference, roughly in that order of importance.

Read together, the cases suggest that collaborative innovation works only when several things line up at the same time: governance, curriculum, faculty development, research orientation, digital infrastructure. Repair one and the remaining four will hold it back. This is also why no model transfers intact, and why each university has to work out which version of it fits the institution it actually is rather than the one described in the policy document. The Quadruple Helix does explain one pattern reasonably well: institutions that engage civil society and environmental concerns alongside industry show broader societal impact than those engaging industry alone, which is what the framework predicts. Digital capability runs through all three cases as an enabler, and that is probably the clearest signal about the decade ahead, since the collaborative models of the 2030s will be shaped substantially by what the technology permits.

Each case also carries costs that an enthusiastic reading would skip. Jimei's multi-dimensional approach consumes administrative capacity at a level a smaller or less well-connected institution could not sustain for long. DMU's research intensity is good for technology transfer and poses a standing risk to undergraduate teaching, because faculty attention is finite and research is where the visible rewards sit. JUST's regional concentration buys tight industrial alignment and may leave graduates with a narrower picture of the global maritime world than their careers will eventually demand. None of these are objections to the models. They are the reason the models have to be adapted rather than copied.

A last observation, about leadership and about memory. In all three universities collaboration began because senior people decided it mattered and were willing to spend political capital making it happen. Personal championship is fragile, though, and it comes with a retirement date. What made the difference over a longer horizon was the construction of capabilities that stopped depending on any individual: liaison offices, transfer mechanisms, faculty development programs, budget lines that recur without having to be argued for each year. Institutionalization of this sort is unglamorous and it is usually left out of accounts of collaborative innovation, which prefer the founding story. It is also what decides whether a partnership is still running once the founding enthusiasm and the pilot funding have both gone.

6 CONCLUSION AND RECOMMENDATIONS

6.1 Key Findings

The paper set out to examine collaborative innovation models in application-oriented maritime undergraduate colleges, read against China's maritime power strategy, and the analysis points one way with some consistency. Bilateral partnership does not do the job. What the situation calls for is the multi-stakeholder innovation ecosystem the Triple and Quadruple Helix literatures describe, along with the governance trouble that comes attached. Five models came out of the review: government-university-industry-research synergies, industry-education integration platforms, project-based training mechanisms, digital intelligence-empowered ecosystems, and international cooperation networks. The three cases say something about what implementation demands, and what it demands is less exotic than the models themselves. Commitment at institutional rather than departmental level. Incentives that reward the behavior being asked for. Digital capability. Governance flexible enough to be rewritten when it turns out to be wrong, which at some point it will. On the evidence assembled here, collaborative innovation reads better as a strategic requirement of maritime power than as an educational reform, since it is the mechanism by which these universities cultivate talent, produce knowledge that somebody uses, and serve regional and national development concurrently rather than one after the other.

6.2 Policy Recommendations

What follows are recommendations, addressed to different parties because the parties face different problems. Government agencies: funding instruments and evaluation frameworks have to reward collaborative outcomes specifically rather than generically, which means curricula industry has validated, technology that has actually moved, graduates employed in work resembling what they trained for. Vague encouragement produces vague compliance. Universities have the cheapest job and the most difficult one, namely rewriting promotion criteria so that industry engagement, applied research, and collaborative teaching count for something. Until that is done every other reform is running against the incentive system, and the incentive system wins. Industry partners need pushing toward co-investment, joint appointments, and agreements measured in years, in place of the transactional engagements that dominate now and that disappear the moment a procurement cycle turns over. On digital infrastructure the case is economic before it is pedagogical: treat it as a public good for maritime education, with shared platforms and common standards, since building it separately at every institution costs more and raises the very barrier it was meant to lower. International cooperation should widen and diversify, with reciprocity and the sustainable development goals as reference points rather than as a closing paragraph. And evaluation of collaborative initiatives belongs in the design, not in the final report, because a failure nobody studied is the most expensive thing a system like this can produce.

6.3 Limitations and Future Research

The limits are worth setting out rather than conceding in a footnote. Case work of this kind buys contextual depth and pays for it in generalizability; quantitative research connecting collaborative practice to measurable outcomes, employment rates, patent filings, revenue from industry, would put the argument on much firmer ground than I can claim for it here. Every institution examined is Chinese, so how far the findings travel is unknown, and comparative international work would help sort what is structural from what is an artifact of one policy environment. Very little has been said about the inside of a collaboration either: who holds power, how trust accumulates or collapses, what happens when the partners want incompatible things. Micro-level organizational study is the right instrument there, and it has barely been pointed at this sector. A fourth limit is technological, since particular platforms date quickly and the durable target for research is the principles of digital-enabled collaboration rather than whichever tool is current. The last gap is longitudinal. Sustainability, adaptation, long-term impact: none of these can be judged from a single point in time, however carefully that point is observed. Closing the gaps would improve the theory and, more to the point, the advice available to institutions working on the maritime power agenda and on sustainable ocean development beyond it.

Three forces will keep reshaping the maritime sector, and they will not arrive in a convenient order: digital transformation, the green transition, geopolitical realignment. The colleges likely to cope are the ones treating collaborative innovation as a core strategy rather than as a set of activities bolted onto an institution that has otherwise stayed the same. The models set out here are a starting point and no more than that. Each has to be fitted to a particular institution's resources, position, and ambitions, and the fitting is most of the work. What finally separates the universities that manage from those that do not is not which template they picked. It is whether they built a culture that stays open, tolerates experiment and the failures experiment produces, and keeps turning outward toward the maritime industry and the public it exists to serve.

COMPETING INTERESTS

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DATA AVAILABILITY

The analysis draws on publicly available policy documents, institutional publications, and previously published secondary research. Every source consulted is listed in the references below. No new empirical data were generated for this study.

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