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Trials, transitions & trajectory of maritime higher education (2025-2035)

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Abstract
The marine industry is rapidly undergoing operational, technological, and regulatory change on a global scale. In light of IMO [1] regulations, technological disruptions, national reforms, and changes in the global labour market, India's maritime education and training (MET) systems will be under increasing pressure over the next ten years to improve quality, integrate cutting-edge technologies, meet global compliance requirements, and provide industry-ready seafarers and maritime higher education. It provides important suggestions for classification bodies, ship owners, training facilities, policymakers, and maritime administration.

Keywords: STCW Convention, DG Shipping, Indian Maritime University, maritime education and training

1. Introduction

India has demonstrated technological resilience and strategic insight in its naval propulsion history, from the smoke-stack period of coal and steam to the clean-burning gaseous fuels of the twenty-first century. In addition to being a legal milestone, the IGF Code [2] opens the door to the next phase of maritime engineering, where the propulsion landscape will be defined by LNG [3], methanol, ammonia, biofuels, hybrid systems, and eventually hydrogen.

Higher education in the maritime sector in India is at a turning point. The future workforce will need advanced skills that go beyond traditional seamanship as the global shipping sector moves toward decarbonisation, digitalization, autonomous technologies, and tighter safety/environmental regulations. A robust, future-ready MET ecosystem is essential given India's position as a major source of seafarers and marine professionals. Over the next ten years, the landscape will change due to upcoming reforms like competency-based training, reorganized curricula, simulation-based evaluations, and improved oversight.

The objectives of this research paper are

- The primary objective is to evaluate how maritime higher education (MHE) must transform between 2025-2035 to remain aligned with technological, environmental and labour-market transitions.
- The secondary objectives are
- To identify the future competency requirements for seafarers and shore-based maritime professionals in the context of automation, digitalisation, decarbonisation, and alternative fuels.
- To assess the adequacy of current MHE curricula, teaching methods, and training infrastructure (simulators, blended learning, and digital platforms) in delivering these emerging competencies.
- To examine institutional and regulatory constraints, including STCW frameworks, accreditation systems, faculty capability, and industry-academia linkages that hinder MHE transformation.

[1] International Maritime Organisation
[2] International Code of Safety for the Ship using Gases or Other Low-Flashpoint Fuels
[3] Liquefied Natural Gas

- To propose a future-oriented, integrative framework for curriculum design, faculty development, quality assurance, and assessment mechanisms relevant for 2025-2035.
- To recommend policy and institutional pathways that enable equitable, scalable, and sustainable transitions in maritime higher education in India (and comparable jurisdictions).

2. Key drivers shaping the future of maritime education

The navigation and seafaring schools founded around the beaches of Mumbai, Kolkata, and Chennai during the colonial era are the origins of India's maritime education. The production of deck and engine workers to assist maritime shipping was the primary focus of these early organizations. The training was narrowly focused, practical, and in line with the requirements of conventional vessels using mechanical and analog equipment.

The system was greatly formalized in the middle of the 20^{th} century with the introduction of the Directorate General of Shipping (DGS) and regular training for sailors. Indian training became even more in line with international standards with the implementation of STCW (Standards of Training, Certification, and Watch-keeping) compliance. However, there were still few options for advanced academic programs or research, and higher education was restricted to diploma-level or certificate courses. The mainstream engineering and managerial fields were isolated from maritime education.

Indian seafaring and ship management firms experienced tremendous expansion during the liberalization era of the 1990s. Competent commanders, marine engineers, and shore-based specialists were in high demand. As a result, a number of private Maritime Training Institutes (MTI) were established, increasing training capacity in pre-sea courses and nautical and marine engineering.

The 2008 Act of Parliament that established the Indian Maritime University (IMU) was a significant turning point. IMU established a national academic framework for maritime higher education, unified marine campuses, and standardized degree programs (B.Sc. Nautical Science, B.Tech. Marine Engineering, Naval Architecture, etc.). During this time,

At this point, the trajectory indicates a change from training that is solely skill-based to formal academic credentials that could facilitate career advancement both on land and at sea.

2.1 Evolution of Regulation

- Stricter audit regimes under IMSAS [4] need more compliance by maritime administrations and METIs [5].
- The STCW Convention and Codes (STCW-F, IGF Code and Polar Operations) are constantly being amended.
- A focus on training infrastructure, faculty competency, quality, and ongoing oversight.

2.2 Technical Interruptions

- The development of autonomous ships, remote operations, smart engine rooms, AI/ML in navigation, and e-navigation systems.
- Advanced simulators, AR/VR training, and digital twins become indispensable educational resources.

2.3 Alternative Fuels and De-carbonization

- A move toward hybrid propulsion, LNG, methanol, ammonia, and hydrogen.
- It becomes necessary to receive training on emergency response, risk management, bunkering safety, and engine operation.

2.4 The need for multidisciplinary skills in the industry

Data analytics, cyber security, environmental compliance, logistics, offshore operations, and ship management are among the skills that marine graduates must possess.

2.5 Reforms in National Policy

- Multidisciplinary integration influenced by NEP [6].
- Encourage more innovation, research, and maritime start-ups.
- Bolstering Indian marine clusters, which include logistics firms, ports, shipyards, and classification organizations.

3. Trials: Present and Emerging Challenges

When steam propulsion was introduced during colonial rule, India's marine modernization got underway. Iron and steel steamships started to coexist with the traditional wooden dhows and sail-powered vessels used along the Indian coast. One of Asia's oldest dockyards, Bombay Dockyard, was a pioneer in the production of auxiliary craft and the maintenance of steamships.

Coal-fired steamships were the mainstay of coastal and international operations by the early 20^{th} century. Large steam fleets run by the British India Steam Navigation Company connected the subcontinent to Southeast Asia, Africa, and the Gulf. Coal, the most common ship fuel at the time, was bunkered in Indian ports like Bombay, Calcutta, Madras, and Cochin.

India inherited a small but significant capacity for ship repair and marine engineering upon its independence in 1947. The fleets of the Shipping Corporation of India (SCI) and other coastal operators continued to use steam propulsion in the early decades of the Indian shipping sector. Additionally, a core cadre of shore-based supervisors and marine engineers who were trained to run boilers, turbines, steam auxiliaries, and coal-fired systems was formed during this time.

- Steam era foundations (Late 19^{th} Century to Mid20^{th} Century)
- Shift to Diesel Propulsion (1960s-1990s)
- The HFO [7] Era and High Capacity Diesel Engines (1990s-2010s)
- Transition from HFO to Low-Sulphur Fuels (2015-2020)
- The IGF Code and the rise of LNG/Methanol Marine Engines (2020-Present)

3.1 Infrastructure and Quality Gaps

Numerous marine institutes still use antiquated simulators, few labs, and inadequate research facilities.

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[4] International Maritime Organization Member State Audit Scheme
[5] Marine Engineering Training Institutes (India)
[6] National Education Policy
[7] Heavy Fuel Oil

3.2 Faculty Shortage and Skills Mismatch
- A small number of young officers are deciding to become teachers.
- Experienced faculty members are retiring.
- The need for educators with new technology training.

3.3 Oversight and Compliance Concerns
- Differences in quality between institutions;
- Non-compliance with academic procedures, evaluations, or record-keeping raises the possibility of international inspection and audit observations.

3.4 Limited R&D [8] Culture
Traditionally, research, innovation, and industry partnership have received little attention in maritime education, which has been primarily focused on teaching.

3.5 Gap between industry expectations and graduate competence
Strong soft skills, digital proficiency, crisis response abilities, and operational readiness from the start are all becoming more and more important to ship owners.
However, curricular rigidity and inadequate exposure to real-world scenarios make it difficult for METIs to deliver.

4. Transitions: Transformative shifts already underway
One of the most revolutionary decades for India's maritime industry is about to begin. The marine higher education scene is changing fundamentally due to a number of factors, including India's aspirations to become a major power, the worldwide shift towards decarbonisation, the rapid growth of technology, and the modernization of shipping rules. The nation's education systems for marine engineering, nautical science, port management, and logistics will change over the next ten years from conventional, classroom-based models to highly digital, dynamic, adaptable, and industry-synchronized ecosystems.

Among the technical changes are
- Installing dual-fuel engines that can run on both MGO [9] and LNG.
- The use of double wall pipes, gas valve units (GVU), and cryogenic storage systems.
- Indian seamen will receive specialized training in LNG handling, bunkering, and emergency response.
- Engine room safety systems for methane detection, ventilation, and explosion control will be upgraded.

As a result, the DGS and Indian Marine Classification Society have extended their regulatory frameworks, authorizing IGF Code training modules and gas-ready designs.

4.1 Simulation-Driven Training
- Full-mission simulators for GMDSS[10], LNG [11], ERS [12], and navigation.
- Rote memorization is being replaced by scenario-based learning.

The foundation of maritime education will include VR[13]-based hazardous environment training, full-mission bridge simulators, engine room simulators, cargo handling simulators, DP simulators, and experiential, scenario-based digital training in place of classroom lectures. Before boarding, trainees will be able to experience engine room emergencies, cargo loading failures, navigating through crowded waterways, and ammonia/hydrogen bunkering threats thanks to VR/AR [14].
The norm will be blended learning, which combines short sea-time modules, simulation-based practice, and digital theory. The DGS and IMU frameworks will probably explicitly recognize e-learning credits.

4.2 Hybrid and Digital Learning
- Online CBT[15]s, digital logbooks, cloud-based learning platforms, and
- Blended learning for theoretical subjects.

The change in marine curricula will be the most noticeable change. Interdisciplinary modules on green fuels, ship electrification, energy systems modelling, advanced navigation systems, digital twins, cyber-security, smart ports, and maritime AI applications will be integrated into degrees like Nautical Science, Marine Engineering, Naval Architecture, Port Management, and Maritime Logistics.
While traditional subjects are still important, the focus is shifting to environmental science, applied technology, predictive maintenance, and system integration. As shipping systems grow more automated, soft skills, crisis management, multicultural communication, and human-element comprehension will become more important.
The "single long-degree" model of higher education will give way to lifelong marine learning. Professionals can rapidly advance their skills in green fuels, maritime cyber-security, ECDIS[16] updates, ballast-water technology, and automation with the use of micro-credentials, short courses, bridge-up programming, and industry-endorsed certificates. Seafarers will be able to transition to shore employment in ports, logistics, marine administration, survey, and compliance with ease thanks to these stackable modules. To co-design such credentials, institutions will collaborate with ports, shipyards, classification bodies, and technology suppliers.

4.3 Practice-Oriented Competence Assessment
- Outcome-based evaluations.
- OSCE [17]-style practical exams.
- Mandatory DP training, improved emergency drills and advanced fire fighting.

4.4 Centres for maritime research and innovation
- Research on decarbonisation, autonomous shipping, and logistics optimization;
- Increasing cooperation with ports, shipyards, and classification societies.

Low and zero carbon technology are quickly becoming the norm in the worldwide maritime sector. Advanced

[8] Research and Development
[9] Marine Gas Oil
[10] Global Maritime Distress and Safety System
[11] Liquid Nitrogen Gas
[12] Engine Room Simulator
[13] Virtual Realty.
[14] Augmented Realty.
[15] Cognitive Behavioural Therapy.
[16] Electronic Chart Display and Information System.
[17] Objective Structured Clinical Examination.

knowledge of alternative fuels like ammonia, hydrogen, methanol, LNG, and battery hybrid systems, as well as carbon accounting, energy efficiency design indexes, and training for both on-board and shore-based professionals, is being pushed into maritime education by international mandates on reducing greenhouse gas emissions, the implementation of green port standards, and India's own Green Shipping Initiative.

4.5 Integration of logistics and port management with maritime education

- Acknowledgment that the maritime workforce now includes shipbuilding,
- SCM [18], offshore services, port operations, and environmental technology.

Digital twins, AI-based navigation systems, automated terminal operations, real-time cargo tracking, block chain-enabled documentation, and cyber-secure shipboard networks are all being used by Indian ports and shipyards. Therefore, from fundamental electronic navigation and marine automation to full training in digital-maritime systems, higher education curriculum must change. Digital literacy, data analytics, cyber-risk management, and remote operations will be prioritized in the upcoming ten years.
The Directorate General of Shipping (DGS) is advocating for competency-based evaluation, continuous assessment, digitized exams, uniform training standards, and quality-driven supervision of Maritime Training Institutes (METs). More standardized, technologically enabled education delivery and assessment will be required as a result of STCW amendments, increased MTI inspections, and India's efforts to raise its profile internationally.
India's port-led industrialization (Sagarmala) [19], shipbuilding growth, offshore energy projects, cruise-tourism developments, and the emergence of new job categories, including sustainability managers, maritime data analysts, autonomous vessel operators, bunker safety specialists, and offshore renewable technicians. As a result, higher education must change.

5. Trajectory: The Next Decade (2025-2035)

India's maritime higher education trajectory reached a revolutionary phase throughout the previous ten years (2013-2024). Indian ships, ports, and shipyards are increasingly using the following forces, which have transformed the industry:

- Cyber-secure networks.
- Engine automation.
- Smart port systems and logistics technologies.
- Digital twins and simulation models.
- Condition monitoring and predictive maintenance.
- Digital navigation and ECDIS.

Graduates must be skilled in software, data, advanced analytics, and system integration in addition to traditional maritime engineering due to this technological transition. The modified curricula from IMU, DGS, and academic partners now include:

- Modern propulsion technology;
- Safety management systems;
- Maritime law and international norms;
- A greater emphasis on electronic navigation;

5.1 Modernization of the MET Ecosystem

- Smart campuses with digital credential systems, AI-based [20] performance analytics, and integrated simulators
- Required reskilling cycles for teachers and students

5.2 India as a Global Centre for Maritime Talent

India has the potential to become

- A major provider of officers and ratings
- An advanced marine training and simulation centre for the area

5.3 Reforming the advanced curriculum

The curriculum will include the following topics:-

- Autonomous vessel operations.
- Cyber security in navigation.
- Analytics-based route optimization.
- Green ship technology.
- Safety training for methanol and ammonia fuel, and
- Maritime artificial intelligence applications.

5.4 Enhanced Maritime Governance

- Improved marine administration digital oversight.
- Real-time training quality monitoring; and.
- Alignment with IMO audit requirements.

5.5 New Employment Domains

- Marine environmental monitoring.
- Offshore wind.
- Coastal shipping and inland waterway logistics.
- Port automation and digital port ecosystems.
- Marine drones and ROV operations.

6. Policy Recommendations

6.1 For marine Administration

- Create a single digital platform to track MET quality;
- Require professors to periodically upgrade their skills;
- Promote research through grants, funding, and contests for marine innovation.

6.2 For MET Establishments

- Improve training facilities and simulators; strategically implement blended learning;
- Form alliances with ports, research facilities, and shipping firms; and
- Offer multidisciplinary electives (AI, cyber security, logistics, and climate science).

6.3 For the Maritime Industry

- Develop programs in collaboration with METIs.
- Offer internships, onboard training opportunities, and real-time case data.
- Encourage automation and decarbonisation research.

[18] Supply Chain Management
[19] It is a Hindi name, is an initiative by the Government of India to enhance the performance of the country's water body logistics
[20] Artificial Intelligence

7. Conclusion
The next ten years will be crucial for India's maritime higher education system. Expanding India's role as a marine nation, safety, environmental stewardship, and global competitiveness all depend on strengthening the MET ecosystem. India can develop a maritime workforce that is prepared to handle both domestic and global issues by embracing technological advancements, regulatory changes and industry-academia cooperation.

India's success in developing a world-class marine workforce capable of advancing the country's blue economy aspirations would depend on its capacity to fortify its maritime education institutions, include industry partnerships, and implement future-oriented curricula.

Therefore the objectives specified earlier has been fully addressed.

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