LR & LR Foundation

WMU WORLD MARITIME UNIVERSITY

Energy | Vessels | Maritime trade | People | Ports

SUMMARY REPORT | JUNE 2026

Digital skills in maritime education and training

A global deep dive into people, skills, and readiness for change

The **Global Maritime Trends programme** was launched by Lloyd's Register and Lloyd's Register Foundation. It is a multi year research initiative that provides evidence, insight and foresight into the major challenges shaping the maritime industry between now and 2050, across all areas from fishing to offshore wind.

The Global Maritime Trends 2050 Report (GMT2050 Report) was launched in 2023 by Economist Impact. It analyses possible future scenarios for maritime in 2050, based on the speed of technology adoption and the level of global collaboration.

The programme includes "deep dive" reports that explore critical maritime issues in more detail. The first "deep dive" into seafarer sustainability and supporting the opportunity for Africa and women to create a sustainable supply of seafarers for the future was released in March 2025. As well as the deep dives, there is also the Global Maritime Trends Barometer, which tracks annual progress in the maritime industry's energy and digital transitions. The Barometer focuses on five key components: maritime trade, energy, vessels, ports and people.

Scan to find out more about the GMT programme.

The World Maritime University (WMU) in Malmö, Sweden, is established within the framework of the International Maritime Organization (IMO), a specialised agency of the United Nations.

The mission of WMU is to be the world centre of excellence in postgraduate maritime and oceans education, professional training and research, while building global capacity and promoting sustainable development.

WMU's vision is to inspire leadership and innovation for a sustainable maritime and oceans future.

WMU is an organisation by and for the international maritime community and is committed to the United Nations 2030 Agenda for Sustainable Development.

This is the second in a series of 'deep dives' following the launch of the Global Maritime Trends 2050 report published in 2023 in partnership with Lloyd's Register Foundation, Lloyd's Register and Economist Impact. The deep dives provide evidence, insight, and foresight on the large-scale challenges affecting the maritime industry over coming years as indicated in Global Maritime Trends 2050. These subsequent reports draw on expert analyses and robust data to provide a comprehensive understanding of the evolving landscape and the potential implications for various maritime stakeholders.

Principal authors

Professor Jens-Uwe Schröder-Hinrichs
Vice President (Strategic Initiatives), World Maritime University

Dr. Renis Auma Ojwala
Research Associate, World Maritime University

Mr. Nguyen Hoang Vuong
Research Assistant, World Maritime University

Professor Momoko Kitada
Academic Dean, Head of Maritime Education & Training,
World Maritime University

Dr. Inga Bartuseviciene
Associate Professor, Maritime Education & Training,
World Maritime University

Ms. Anne Pazaver
Lecturer, Maritime Education & Training, World Maritime University

Executive summary

This report examines the development of digital skills among seafarers, addressing the challenges that arise from the growing adoption of digital technologies and increasing automation in the maritime sector. Technologies such as automated navigation systems, smart shipping solutions, digital logistics platforms, and online training tools are reshaping how ships are designed, operated and regulated. At the centre of this transformation is a critical and often underexamined question: are today's maritime education and training systems equipping seafarers and maritime professionals with digital skills needed to navigate a sustainable future?

It also examines how digital skills are understood, developed and applied across maritime institutions from policymakers and education providers to the industry players and seafarers themselves. Rather than treating digitalisation as a purely technological challenge, the study positions it as a human capability imperative, where skills, competencies and institutional readiness determine whether digital innovation delivers environmental and operational gains.

Drawing on a robust mixed methods approach, the report connects global policy ambitions with operational realities at sea and in training institutions. It surfaces gaps between regulatory intent and on-the-ground implementation, highlights emerging good practices and identifies leverage points where targeted action can accelerate progress. In doing so, the report offers maritime stakeholders, including decision-makers a clear, evidence-informed perspective on how strategic investment in digital skills development can strengthen maritime education and training, enhance workforce resilience and support the sector's transition towards a more sustainable and future-ready maritime industry.

Data gathering

This study adopted a mixed methods approach that blended quantitative evidence with qualitative insight. This design allowed perspectives from policy, education, industry and seafaring practice to be examined together, ensuring a well-rounded and credible evidence base. By triangulating multiple data sources, the study strengthened the robustness and reliability of its findings.

Data were collected through five complementary streams:

1. Literature review:

The study drew on an extensive review of literature relevant to the maritime sector, focussing on maritime digital skills. **More than 300 academic publications,** policy documents, institutional and industry reports were reviewed to explore four themes:

- The role of digital transformation in maritime operations and sustainability, including key drivers and enablers.
- Emerging digital skills required in the maritime sector.
- Current approaches to Maritime Education and Training (MET) for developing digital skills.
- Challenges and opportunities associated with integrating digital and sustainability principles into seafarer training.

Insights from the literature and the Technology Adoption (TechAdo) model informed the design of the stakeholder analysis and survey tools.

2. Document analysis:

This identified patterns in country and regional engagement in international policymaking. The documents submitted to the Maritime Safety Committee (MSC) and the Human Element, Training and Watchkeeping (HTW) Sub-Committee between 2018 and 2025 were studied, because the year 2018 marked the beginning of significant discussions on Maritime Autonomous Surface Vessels (MASS) and the full implementation of the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers, 1978 (STCW) Manila Amendments. **A total of 2,092 MSC submissions and 336 HTW submissions** were analysed to gain a better understanding of the discussions relating to seafarers' digital skills and maritime digitalisation, and which countries are actively contributing to the International Maritime Organization (IMO) discussions.

3. Key informant interviews:

These helped to identify and understand the roles, interests and influence of stakeholders in the development of digital skills within the sector. The stakeholders for these interviews were maritime administrations, industry players and Maritime Education and Training Institutions (METIs). The analysis draws on **110 interviews** across the stakeholder groups: 47 from METIs from 18 countries, 37 government officials from 11 countries, and 26 industry experts from 13 countries.

4. Seafarer survey

This provided evidence of current skill levels, challenges, and training needs. The survey was conducted online using QuestionPro and distributed through professional seafarer networks, training institutions and maritime organisations. It examined current levels of digital skills among seafarers, access to and experience with digital training resources, perceptions with digital transformation and its implications for maritime sustainability, and barriers and enablers to digital skills development. **A total of 532 responses** were received and the participant profile reflects a broad and globally diverse cross-section of the maritime workforce.

5. Validation workshops

These tested and refined findings, and also offered expert perspectives on pathways for digital transformation within MET. **Three validation workshops** were held with 23 participants drawn from shipping companies and industry organisations, seafarers, maritime administrations, regulators and academia. Each workshop involved between five and ten participants and was facilitated using a semi-structured discussion guide to encourage open dialogue, after a presentation of the preliminary findings by the research team.

Forewords

Digital technologies are reshaping the maritime industry at pace. From how vessels are operated and maintained, to how decisions are made on shore, digitalisation is changing not just systems, but the everyday realities of work and risk across the sector. At Lloyd's Register Foundation, we believe it is vital to understand what this shift means for people and for safety.

We are an independent charitable foundation, driven by evidence and focused on public benefit. Our work starts from a simple premise: safety and people must sit at the heart of any digital transition. Digitalisation in maritime is more than a technical shift as it changes how people work, how decisions are made, and how risks are understood and managed. This raises the question of whether people are being prepared for the realities of an increasingly digital operating environment. Skills gaps are therefore not abstract workforce challenges - they are safety risks with this deep dive focusing on people, not platforms.

Dr. Jan Przydatek
Director of Technologies
Lloyd's Register Foundation

This Deep Dive examines a growing mismatch. Based on a global survey of 532 seafarers across 64 countries, plus interviews with educators, regulators and shipping companies, it reveals a clear pattern: technology adoption is moving faster than training standards, instructor capability and certification frameworks. Innovation is outpacing preparedness.

Closing this gap is not about adding more training courses. Digital competence and assurance are inseparable. Technology only improves safety when people understand how systems work, trust their outputs, and know when not to rely on them. As automation, data driven systems and remote operations become embedded in everyday practice, human judgement, confidence and competence remain central.

Mark Warner
Global Client Marketing Director
Lloyd's Register

Maritime digitalisation is no longer a distant prospect. It is already reshaping how ships are designed, navigated, regulated, and sustained. The question is not whether the industry will continue to transform, but rather whether the workforce will be ready. At the World Maritime University, we start from the recognition that digital transformation depends on people as much as on technology.

Achieving true digital transformation requires a skilled workforce. The ability of seafarers and maritime professionals to understand, adopt, and apply digital tools will determine whether the industry can fully realise the benefits of this transition. It is within this context that this report makes its contribution. We hope that this report will inform policy and decision-making, guide industry practice, foster collaboration, and inspire meaningful action across the global maritime community.

Professor Maximo Q. Mejia, Jr.
President,
World Maritime University

Key Findings

The most important finding is that the maritime workforce, institutions, and regulatory frameworks are not keeping pace with the industry's accelerating digital transformation. Based on a global survey of 532 seafarers across 64 countries and in-depth interviews with 110 stakeholders from METIs, maritime administrations, and industry players across more than 20 countries, this study assesses the current state of digital skills in maritime education and training, identifies the key challenges, and outlines the actions needed to future-proof the maritime workforce.

(Source: IAMU FY2025 project led by Dr. Johan Bolmsten at WMU)

1.

Digital skills are multi-layered

There is no shared definition of maritime digital skills, and this ambiguity is itself a barrier to progress. Stakeholders interpret "digital skills" differently depending on their role and context, ranging from basic computer literacy to advanced competencies in data analytics, AI, and remote operations. This study identifies four progressive layers of digital competence required in the modern maritime workforce:

Basic skills: Foundational digital literacy (confident use of computers, software, and digital interfaces) and cybersecurity awareness (recognising threats, understanding vulnerabilities, and maintaining secure practices).

Specialised skills: Competence in the use of maritime-specific systems including ECDIS, AIS, GMDSS, automated engine systems, and digital cargo monitoring platforms.

Advanced skills: Interpretation of operational data, understanding of digital system architecture for troubleshooting, and adaptability to technology development.

Future skills: Proficiency with AI, machine learning, and remote and shore-based operations.

Digital skills do not replace traditional seafaring skills. They build upon them. Effective digital competence requires the integration of technological knowledge with human judgement and operational expertise. Age and experience are significant contextual factors: younger seafarers often demonstrate greater comfort with digital interfaces, while mid-career and experienced professionals bring the operational depth that digital tools require to be used safely and effectively.

2.

Seafarers are willing to upskill, but face significant training barriers

Motivation is not the obstacle to digital upskilling. Two-thirds of surveyed seafarers (67 percent) expressed willingness to participate in digital upskilling programmes, and fewer than 5 percent said they did not see a need for it. Yet the provision of training falls far short of this appetite: more than 80 percent of seafarers have received digital skills training either never or less than once a year, and 72 percent report inadequate time to familiarise themselves with new digital systems onboard.

The gaps that seafarers identify as most pressing are concentrated in emerging technologies rather than established tools. Automation and AI-assisted decision-support systems, programming and coding, and data network management are the areas where seafarers feel least prepared. By contrast, they report greater confidence with conventional navigation and communication systems. This pattern signals that digital transformation is outpacing training provision, particularly for the technologies that might emerge in the next generation of shipping.

Seafarers consistently rate onboard training and simulator-based learning as the most effective methods for building digital competence, valuing hands-on and context-specific approaches over classroom instruction. The low familiarity with VR and AR reflects limited access rather than resistance; where seafarers have used these tools, ratings are more positive. A recurring concern is the misalignment between shore-based training and the digital systems actually encountered onboard: only 12 percent of seafarers report that shore-based training "always" reflects their onboard reality.

An additional issue highlighted by seafarers and validated through stakeholder workshops was the question of training timing and compensation. E-learning and digital familiarisation tasks often fall outside formal duty hours, raising important questions of fairness and compliance that the industry has yet to fully address.

3.

METIs are advancing, but key barriers constrain progress

METIs are actively responding to digital transformation, but progress is uneven and constrained by intersecting challenges. Among the strategies most widely pursued, 57 percent of METIs prioritise collaboration, knowledge exchange, and industry partnerships, while 46 percent focus on expanding digital infrastructure and 41 percent are reforming curricula. Despite this momentum, however, access, equity, and financial support are addressed by only 11 percent of institutions – a striking gap given how widely financial constraints are identified as a barrier.

The most commonly cited barrier to technology adoption in METIs is insufficient digital competence among teaching staff (51 percent of participants), followed closely by limited financial resources (46 percent). Curricula in many institutions remain overloaded and slow to adapt, constrained by regulatory requirements and institutional inertia. Cultural resistance to change, generational differences among instructors, and a shortage of faculty with both current seagoing experience and digital expertise compound the challenge. Critically, instructor qualification frameworks do not yet include formal requirements for digital competence, leaving a systemic gap at the heart of maritime training.

The digital tools in use across METIs reflect varying levels of maturity. Simulators, ECDIS, and computer-based training are well established. AI, augmented and virtual reality, digital twins, and robotics are gaining interest but remain unevenly adopted. Future plans are ambitious: 97 percent of METIs identify curriculum alignment with industry needs as a top priority, but with funding cited by just 3 percent as a forward-looking strategy, the gap between aspiration and resource is a defining concern for the sector.

4.

Regulatory frameworks are not keeping pace with technological change

The STCW Convention, last substantially updated in 2010, does not yet reflect the digital realities of modern shipping. References to digital competence within STCW remain limited and largely implicit, with emerging skills such as cybersecurity, data literacy, AI operation, and remote vessel management absent from formal requirements. The ongoing STCW comprehensive review has identified some 500 gaps in current standards, signalling growing recognition of the problem, but the timeline leaves a decade-long window of misalignment.

Maritime administrations and METIs broadly recognise that technology evolves far faster than international regulation can follow. This creates uncertainty at every level: educators do not know which competencies to embed in curricula, companies cannot align training investments with confirmed future requirements, and seafarers face a shifting skills landscape without clear guidance. The regulatory lag is particularly acute for decarbonisation technologies, cybersecurity, and MASS, three areas identified by administrations as the most pressing digital skills priorities for the coming decade.

5.

Adaptation trends in digital transformation: Four approaches among METIs

Maritime education institutions across different countries covered in this report display four distinct organisational cultures when responding to digital transformation, each reflecting different priorities, resources, and relationships with regulation:

Proactive institutions act ahead of regulatory requirements, embedding digital skills throughout their curricula and treating them as essential competencies rather than compliance exercises. This approach reflects an institutional culture oriented towards shaping the future workforce rather than certifying compliance with current standards.

Compliant institutions wait for regulatory clarity before committing to curriculum change. This is not inertia but often a practical response to systems requiring formal approval, where early action carries financial and operational risk. This is the most common type observed across the study. Some institutions within this type actively look for ways to exceed minimum requirements through instructor-led initiatives or industry partnerships, while maintaining a compliance-oriented stance towards formal curriculum.

Adaptive institutions find creative ways to integrate digital tools despite constrained resources, using e-learning platforms, digital assessments, and open-access tools to build baseline digital competence without expensive simulation equipment. However, infrastructure gaps remain a significant barrier: many lack bridge and engine room simulators, limiting graduates' practical exposure to the systems they will encounter onboard.

Strategic institutions pursue collaborative solutions under resource constraints, establishing clusters, research centres, and industry partnerships to achieve more advanced digital education over time. These institutions recognise curriculum gaps and develop clear strategies to address them, but face budget limitations that require coordinated rather than individual institutional responses. The cluster model - pooling government, industry, and institutional resources to share simulation infrastructure costs - offers a practical and replicable pathway forward.

These patterns cut across regions. Each type can be found in multiple countries, and more than one type can exist within the same nation or even the same institution at different times. The categories describe dominant tendencies, not fixed identities.

(Source: WMU)

6.

Digitalisation presents a dual dynamic for equity

Digital platforms and e-learning tools have enabled institutions with limited physical infrastructure to provide foundational digital literacy and access to current training content that would previously have required costly resources. However, advanced digital training capability, high-fidelity simulation, cybersecurity environments, autonomous vessel familiarisation require substantial and continuous investment that many institutions cannot sustain. Institutions in regions with active domestic shipping industries benefit from equipment donations and technology transfer that supplement their budgets, while those without such partnerships must purchase all equipment commercially. This structural inequity is intensifying rather than diminishing with digital transformation.

The asymmetry in IMO regulatory participation reinforces these concerns: European countries contributed 174 submissions to HTW Sub-Committee sessions 5 - 11, compared to only 4 from African countries. Countries that engage more actively in IMO processes have greater influence over the global training standards that all member states must eventually implement, raising questions about whether the resulting standards reflect the realities of under-represented countries.

7.

Policy implications

Policy implications point to the need for greater regulatory clarity from IMO on the training requirements associated with emerging technologies such as MASS, targeted support mechanisms for institutions in resource-constrained environments, and sector-wide investment in instructor digital capacity development. Without coordinated international responses to these structural challenges, the risk is a widening gap between what seafarers are certified to do and what the industry increasingly requires them to know.

Conclusions

The report underlines that the rapid digitalisation of maritime operations is transforming ship management, navigation systems, and maritime logistics networks. Emerging technologies such as advanced sensor systems, autonomous navigation, AI, and maritime data platforms are reshaping operational practices across the global maritime industry.

Digital skills in the maritime sector are not isolated competencies; rather, they are deeply intertwined with traditional seafaring and operational expertise. The findings reveal a persistent digital skills gap shaped by factors such as age, experience, exposure to technology and education. This demonstrates that digital skills are multidimensional, dynamic and essential for both operational effectiveness and human-centred maritime practice.

Seafarers are increasingly expected to interpret complex digital information, evaluate system reliability, and adapt to rapidly evolving technologies while maintaining safe and efficient vessel operations. This highlights that the digital skills in the maritime context require not only technological familiarity, but also critical thinking and professional judgement.

However, a persistent disconnect remains between MET and industry expectations. While MET institutions are increasingly integrating foundational digital skills through simulations, modelling and computer-based training, more advanced competencies such as data analytics, cybersecurity, AI literacy, and sustainable digitalisation remain underdeveloped.

The successful implementation of digital transformation will therefore depend on coordinated efforts to develop seafarers' digital skills and align them with evolving operational demands. At present, significant barriers remain, including the lack of a shared definition of "digital skills" among maritime stakeholders.

The need for coordinated action is further underscored by the wide range of gaps identified in the ongoing comprehensive review of the STCW Convention. MET institutions, maritime administrations, and industry players must therefore shift from reactive to proactive roles, taking joint responsibility in policy development, research, and innovation to keep pace with technological disruption.

Curriculum alignment is most effective when institutions maintain continuous dialogue with industry, engage guest lecturers, and validate learning outcomes through hands-on training and simulation-based learning. Nevertheless, the rapid pace of technological change continues to create uncertainty regarding the skills required for future maritime operations.

Finally, without targeted investment in digital skills development and research, particularly in developing regions, existing global disparities are likely to widen, jeopardising not only equity but also maritime safety and resilience. The future of shipping therefore depends on addressing these gaps proactively and collectively.

Recommendations

STAKEHOLDER

Seafarers and onboard personnel

- Transition from technology users to digitally competent operators of cyber-physical ship systems.
- Critically analyse system outputs, identify anomalies, and collaborate with shore-based IT/OT specialists to resolve operational challenges.
- Maintain foundational digital literacy, including shipboard management systems, digital data interpretation, and basic troubleshooting.
- Develop solution-oriented competencies, particularly among senior officers, to translate operational challenges into technical requirements and engage effectively with IT/OT teams and OEMs.
- Treat cybersecurity as a core safety responsibility through awareness, compliance, and scenario-based training.
- Use digital and automated systems as decision-support, maintaining situational awareness and critical judgement.
- Apply digital tools responsibly, considering operational efficiency, environmental impact, and crew safety.
- Commit to lifelong learning and continuous upskilling as digital technologies evolve.
- Share positive and hands-on experience to enhance peer learning onboard.

STAKEHOLDER

Maritime Education and Training (MET) Institutions

- Integrate digital skills across curricula, linking theory, practice, and industry requirements.
- Embed cybersecurity, data literacy, AI awareness, digital sustainability, and both traditional and emerging skills into core learning outcomes.
- Maintain a strong focus on foundational skills while integrating new digital technologies (provide basic IT foundations while preparing students for emerging technologies).
- Regularly modernise curricula to reflect automation, alternative fuels, low- and zero-carbon shipping, and emerging technologies (remove obsolete/ outdated content).
- Expand experiential learning through simulators, virtual labs, single window systems, and digital twins particularly where sea time is limited.
- Ensure inclusive access to digital learning, using mobile-friendly and low-bandwidth solutions to reach diverse learner groups.
- Enhance instructor capability through recruitment of digitally competent educators, structured induction, continuous professional development, and institutional knowledge sharing.
- Offer financial and institutional support for faculty training and curriculum innovation.

STAKEHOLDER

Maritime Administrations and Governments

- Develop national digital competency frameworks aligned with international conventions and industry needs, contributing to a globally consistent, technology-neutral baseline of maritime digital skills through close collaboration among METIs, industry, and regulators to ensure continuous alignment with evolving competence requirements.
- Fund MET modernisation, including simulators, digital laboratories, and cybersecurity training infrastructure.
- Promote equitable access to digital education by improving connectivity, affordability, and addressing infrastructure gaps affecting cadets and seafarers.
- Integrate maritime digital skills into broader national strategies for digitalisation, sustainability and workforce development.
- Support research, innovation, and pilot programmes in METIs to test and scale effective digital training models.
- Enhance policy frameworks for standardisation of digital skills.
- Strengthen industry and international collaboration to improve coherence and alignment across stakeholders.

STAKEHOLDER

International Regulatory Bodies

- Establish baseline and scalable digital competency standards for seafarers, comparable to STCW language proficiency standards.
- Ensure competency frameworks are flexible and future-proof that can evolve alongside technological change.
- Update conventions, codes and model courses to include automation, AI, cybersecurity and remote operations (accelerate review and update cycles for conventions).
- Embed human-centred principles in digitalisation policies to ensure safe crewing, workload management and seafarer wellbeing.
- Engage METIs, industry and research communities to ensure regulatory updates are realistic and implementable (or educationally feasible).
- Strengthen collaboration between METIs, industry, and regulators.

STAKEHOLDER

Shipowners and Shipping Companies

- Provide company-specific digital induction and continuous access to onboard and shore-based learning resources for seafarers.
- Support continuous professional development throughout seafarers' careers in response to evolving digital systems.
- Share operational data, incident insights, and system feedback with METIs to align training with real-world conditions.
- Foster a strong digital safety and cybersecurity culture onboard, supported by scenario-based training.
- Manage digital workloads and system complexity to protect human performance and wellbeing.
- Participate in industry-wide initiatives to harmonise digital skills requirements across fleets and vendors (reduce skill fragmentation).
- Align academia and industry through bidirectional communication to better integrate training with operational needs.

STAKEHOLDER

Industry Stakeholders and Technology Developers

- Apply user-friendly design principles, with field testing and iterative development involving seafarers and trainers.
- Ensure digital systems are usable, safe and trainable within operational and educational constraints (or under real operational conditions).
- Collaborate with METIs to align technology design with training needs.
- Support standardisation and interoperability to reduce cognitive load and training complexity.
- Share best practices, guidance, and contribute to technical standards and competency via class societies and industry bodies.
- Increase access to operational digital tools for training purposes.

STAKEHOLDER

Cross-Stakeholder and Shared Responsibilities

- Strengthen industry-academia collaboration through curriculum co-design, joint research and knowledge exchange.
- Actively participate in international and national regulatory processes to align policy, education and operations.
- Establish continuous feedback loops linking policy, training, technology deployment and operational experience.
- Promote adaptive governance mechanisms to ensure digitalisation enhances safety, sustainability and social responsibility.
- Coordinate actions to create a coherent, equitable and future-oriented digital skills environment for the global maritime sector.
- Engage in STCW revisions to integrate digital competencies globally.
- Increase funding and institutional support to modernise MET infrastructure and training capabilities.
- Balance traditional and emerging skills to prepare seafarers for current and future operational environments.

Please also read the previous report:

Deep dive on seafarer sustainability: Supporting the opportunity for Africa and women to create a sustainable supply of seafarers for the future

www.lrfoundation.org.uk/publications/deep-dive-on-seafarer-sustainability

Foundation

WORLD MARITIME UNIVERSITY

Energy

Vessels

Maritime trade

People

Ports