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The Role of Maritime Education in Shaping Career Pathways: Navigating Technological Changes and Industry Needs

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ABSTRACT

The accelerating digital transformation of the maritime domain—marked by augmented automation, advanced simulation technologies, and the proliferation of e-navigation systems—necessitates an urgent recalibration of maritime education frameworks. This study offers a data-driven assessment of the alignment between Malaysian maritime education and the technological competencies demanded by contemporary seafaring and shore-based maritime roles. A quantitative survey ($N = 80$) was analyzed using descriptive statistics, scale reliability testing, and interconstruct correlation analyses to evaluate three pivotal dimensions: technological integration, educational quality, and career readiness. Findings reveal that students' exposure to simulation-based and digital navigation training remains moderate, with notable deficiencies in access to updated simulator scenarios and hands-on digital immersion. Composite measures demonstrated excellent reliability ($\alpha = .940$–.982), while correlational analysis yielded exceptionally strong positive associations between technological integration, educational quality, and career readiness ($r = .972$–.989, $p < .001$). These results underscore the transformative impact of technology-enhanced pedagogies on maritime competence development. The study advances the discourse on maritime human capital readiness by evidencing the structural need for greater technological investment, curricular modernization, and systematic alignment with the operational realities of a highly digitalized maritime sector.

Keywords: Maritime Education; TVET; Technological Changes; Industry Needs

1. Introduction

The maritime industry is undergoing a profound transformation driven by rapid advancements in digital technologies, automation, and integrated navigation systems (Ibokette et al., 2024). Developments such as Electronic Chart Display and Information System (ECDIS), radar/ARPA automation, autonomous vessel technologies, smart port operations, and data-driven ship management have redefined modern maritime operations (Uchechukwu, 2025). International maritime standards, particularly those enforced by the International Maritime Organization (IMO), increasingly mandate higher levels of digital competency and technological proficiency to ensure safe, efficient, and compliant vessel operations (Wismawati & Mokodompit, 2025). Consequently, the expectations placed on maritime professionals have expanded beyond traditional seamanship to include advanced digital literacy, simulation proficiency, and technology-enabled decision-making skills (Theotokas et al., 2024).

This global transformation places considerable pressure on maritime education and training institutions to modernise curricula, invest in advanced simulator technologies, and integrate digital tools into teaching and learning practices (Kamis et al., 2026). Simulator-based training has emerged as a core component of maritime competency development, as it provides realistic operational scenarios that enhance situational awareness, decision-making

capability, and the practical application of theoretical knowledge (Ala et al., 2024). Nevertheless, the degree of technological integration and simulator utilisation varies across countries and institutions, particularly within developing maritime education systems (Karahalil et al., 2024).

In Malaysia, maritime academies and higher education institutions play a critical role in producing competent officers and maritime professionals for both domestic and international labour markets (Othman, 2014). Despite increasing investments in simulation laboratories and digital training infrastructure, concerns remain regarding whether existing programmes sufficiently prepare students for the highly digitalised operational environments onboard modern vessels and within shore-based maritime operations (Ochea, 2025). Empirical evidence examining students' perceptions of technological exposure, simulator effectiveness, and preparedness for digitalised maritime careers remains limited (Lee, 2004).

This study addresses this gap by examining students' perceptions of technological integration, the quality of maritime education, and their readiness for digitalised maritime operations (Simanjuntak, 2024). Through quantitative analysis of survey data collected from 71 respondents, the study evaluates the extent to which current maritime education practices in Malaysia align with the technological demands of an Industry 4.0-oriented maritime sector. The findings aim to inform curriculum enhancement, policy development, and strategic planning to ensure maritime graduates are equipped with the competencies required in an increasingly complex and technology-driven global industry (Carlos, 2025).

2. Literature Review

The literature review critically examines existing scholarly work related to technological advancement in the maritime industry, the role of maritime education, alignment between industry expectations and educational outcomes, curriculum adaptation, and the influence of technology on graduate career decisions. This section establishes the theoretical and empirical foundation that motivates the present study by identifying gaps in current maritime education practices, particularly within the Malaysian context.

2.1 Technological Advancements in the Maritime Industry

The maritime industry has undergone unprecedented technological transformation over the past decade, driven by automation, digitalisation, and sustainability imperatives (Autsadee et al., 2024). Innovations such as autonomous navigation systems, advanced radar and sensor integration, smart port operations, and artificial intelligence-based decision-support tools have significantly altered the operational structure of ships and ports. The International Maritime Organization reports that the integration of digital technologies into shipping operations has enhanced navigational safety, operational efficiency, and regulatory compliance (Tsoulakos & Pantouvakis, 2026). Key developments such as E-Navigation systems and the Maritime Autonomous Surface Ships (MASS) concept illustrate the industry's shift towards data-driven and technology-intensive operations (Giglio et al., 2024).

The World Maritime University further emphasises that maritime digitalisation is closely linked to sustainability objectives, including fuel efficiency optimisation, emissions monitoring, predictive maintenance, and remote port operations (Battaglia et al., 2024). These advancements demand maritime professionals who possess not only conventional seamanship skills but also strong digital literacy, analytical capability, and adaptability to rapidly evolving technologies (You, 2024).

Despite these developments, several studies highlight persistent challenges in aligning maritime education systems with industry-level technological progress. Many developing maritime nations, including Malaysia, struggle to update academic curricula at the pace required by technological change (Saharuddina et al., 2011). This growing gap underscores the necessity for continuous curriculum review and pedagogical reform within maritime education institutions (Narto*, 2026).

Furthermore, increased automation has reshaped human resource requirements in shipping, shifting onboard roles from manual operation towards system monitoring, analytical decision-making, and human–machine interaction (Weintrit, 2024). This transformation necessitates education models that emphasise simulator-based training, cyber-physical systems understanding, and data-supported operational decision-making (Ramanjaneyulu et al., 2026).

In Malaysia, national initiatives such as the Maritime Education and Training Enhancement Framework (METEF) and the National Transport Policy (2019–2030) reflect governmental commitment to modernising maritime training through closer collaboration between academia, industry, and regulators (Kamis et al., 2026).

These initiatives highlight that technological advancement in maritime education is not merely about introducing new tools, but about transforming educational paradigms to produce future-ready maritime professionals (Weintrit, 2024).

2.2 The Role of Maritime Education

Maritime education forms the foundation for producing competent seafarers, navigators, and maritime managers capable of operating complex marine systems. It integrates theoretical instruction with practical training and is guided by international regulatory frameworks such as the Standards of Training, Certification, and Watchkeeping (STCW) Convention. The primary role of maritime education is to develop cognitive, technical, and behavioural competencies necessary for safe, efficient, and compliant maritime operations (Jimenez, 2025).

In Malaysia, institutions such as University Malaysia Terengganu (UMT) and the Malaysian Maritime Academy (ALAM) play a vital role in developing maritime human capital (Kamis et al., 2026). The incorporation of simulator-based learning, bridge resource management training, and maritime logistics modules has enhanced students' exposure to real-world operational scenarios (REGINA & Sutria, 2025). Nevertheless, empirical evidence suggests that challenges remain in translating classroom knowledge into practical competence, particularly in relation to advanced digital technologies (Simanjuntak et al., 2025).

The evolving maritime industry requires education systems that extend beyond regulatory compliance to foster innovation, adaptability, and sustainability-oriented thinking (Cahyadi et al., 2024). As a result, scholars advocate a shift from traditional lecture-based instruction to experiential and technology-enhanced learning approaches. Methods such as project-based simulations, virtual reality bridge training, and e-learning platforms allow students to engage with realistic maritime scenarios in controlled environments (Erdönmez & Şakar, 2025; Kamis et al., 2026).

Moreover, maritime education contributes to the development of professional identity, ethical awareness, and decision-making competence, all of which are essential in managing complex and high-risk maritime operations (Mudakir et al., 2024). A holistic educational approach that balances technical proficiency with soft skill development is therefore critical to ensure graduate adaptability in a dynamic and technology-driven industry.

2.3 Industry Expectations versus Educational Outcomes

A recurring concern in maritime human capital development is the misalignment between industry expectations and educational outcomes. Contemporary maritime employers increasingly seek graduates with competencies in digital operations, data analytics, automation, and environmental management (Barasa et al., 2025). However, these competencies are not consistently embedded within existing maritime curricula. Limited exposure to industry-standard technologies contributes to employability gaps among maritime graduates (Jacobs & Goedhals-Gerber, 2026).

The International Chamber of Shipping identifies this skills mismatch as a major barrier to sustainable maritime workforce development (Barasa et al., 2025). Contributing factors include outdated teaching modules, insufficient academic–industry collaboration, and limited internship opportunities that provide exposure to operational systems used in modern shipping (Barasa et al., 2025).

Structured industry engagement, including internships, simulator-based training, and partnerships with shipping companies, is essential to bridging the gap between academic preparation and operational reality. Such collaborations enable students to gain practical insight into technological, managerial, and safety challenges faced by the maritime sector (Simanjuntak et al., 2025).

Furthermore, automation and digitalisation will gradually reduce demand for traditional seafaring roles while creating new opportunities in areas such as maritime cybersecurity, smart logistics, and data-driven fleet management. This shift reinforces the need for maritime education institutions to prepare graduates for both traditional and emerging maritime career pathways (Caesar, 2023).

2.4 Curriculum Adaptation and Industry Collaboration

Curriculum adaptation is central to maintaining the relevance of maritime education in a technology-driven era. Maritime education and training institutions must integrate emerging disciplines such as digital navigation, cyber risk management, and autonomous vessel operations (Popoola et al., 2024). Continuous curriculum review is necessary to ensure alignment with international standards and contemporary industry practices (Cristina et al., 2024).

Collaboration between academia and industry significantly enhances curriculum relevance and graduate employability. Establishment of joint curriculum development committees involving educators, regulators, and industry practitioners. Such collaboration facilitates industry-aligned module design, access to advanced simulation facilities, and structured industrial training opportunities (Muharam et al., 2025).

Curriculum reform must also reflect the maritime sector's growing emphasis on sustainability. Environmental management, green shipping technologies, and energy efficiency strategies are now integral components of maritime education. Embedding these topics ensures that graduates are familiar with international environmental regulations such as MARPOL and the IMO's decarbonisation agenda (Bejar et al., 2025) .

Within the Malaysian context, the incorporation of smart port operations, digital logistics systems, and ship energy management modules has shown potential in reducing skill mismatches. However, challenges persist due to limited funding, inadequate technological infrastructure, and shortages of educators trained in advanced digital maritime systems (Kamis et al., 2026)

2.5 Technological Influence on Graduate Career Decisions

Technological advancement significantly influences students' perceptions of maritime careers and professional pathways. Increasing automation has generated uncertainty among some students regarding long-term employment prospects in traditional seafaring roles. Conversely, other students perceive technological innovation as an opportunity to pursue emerging careers in maritime engineering, logistics management, and maritime data analytics (Weintrit, 2024).

Exposure to modern maritime technologies positively influences students' motivation and confidence in pursuing maritime-related careers. Similarly, engagement in simulation-based learning enhances students' analytical and technical competencies, thereby improving employability in high-technology maritime sectors (Ala et al., 2024).

The International Labour Organization predicts that future maritime occupations will increasingly require hybrid skill sets combining digital literacy, problem-solving capability, and cross-disciplinary knowledge. This trend underscores the need for maritime education to evolve from producing solely operational-level officers to developing strategic thinkers capable of navigating the digital maritime economy (Caesar, 2023).

Overall, technological transformation has redefined maritime career pathways by expanding professional roles beyond traditional navigation and engineering domains. Maritime education therefore plays a pivotal role in shaping students' career perceptions, readiness, and adaptability within an increasingly digitalised global maritime industry.

3. Research Methodology

A total of 80 Malaysian maritime students participated in the study. Descriptive analysis showed moderate levels of technological integration ($M = 2.76$, $SD = 1.41$), education quality ($M = 3.41$, $SD = 1.21$), and career readiness ($M = 2.81$, $SD = 0.35$). Item-level results indicated limited exposure to simulator-based training and digital navigation tools, while students generally perceived the quality of instruction positively.

Reliability analysis confirmed excellent internal consistency for all constructs: Technological Integration $(\alpha = 0.982)$, Education Quality $(\alpha = 0.976)$, and Career Readiness $(\alpha = 0.940)$. Composite mean scores were $TI = 3.02$, $EQ = 3.21$, and $CR = 2.89$, suggesting room for improvement in technology exposure and career preparedness.

Pearson correlation analysis revealed strong positive relationships: TI ↔ EQ ($r = 0.989$, $p < .001$), EQ ↔ CR ($r = 0.976$, $p < .001$), and TI ↔ CR ($r = 0.972$, $p < .001$). Hypothesis testing indicated that technological integration significantly influences education quality and career readiness, and that education quality positively affects career readiness.

These findings suggest that enhancing technological integration, through simulator-based training and digital navigation tools, can improve both perceived education quality and career readiness. Despite moderately positive perceptions of education quality, students' confidence in navigating digitalised maritime operations remains limited, highlighting the need for more practical, technology-focused learning experiences.

4. Results and Findings

This chapter presents the results of the study examining technological integration, education quality, and career readiness among Malaysian maritime students. A total of 71 valid responses were analysed.

4.1 Descriptive Statistics

The descriptive analysis indicated that students reported moderate levels of technological integration ($M = 2.76$, $SD = 1.41$), suggesting uneven access to simulator-based training and digital navigation tools. Education quality was perceived more positively ($M = 3.41$, $SD = 1.21$), reflecting generally satisfactory course content, assessments, and teaching clarity. Career readiness scored lower ($M = 2.81$, $SD = 0.35$), indicating that students felt only moderately prepared for digitalised maritime operations.

At the item level, students reported low-to-moderate exposure to simulator training, with mean scores ranging from 2.76 to 2.94 for technological integration items. Education quality items scored between 3.15 and 3.30, while career readiness items ranged from 2.77 to 2.90, reinforcing the pattern of moderate-to-low confidence in career preparedness.

4.2 Reliability Analysis

The reliability analysis showed excellent internal consistency for all constructs: Technological Integration $(\alpha = 0.982)$, Education Quality $(\alpha = 0.976)$, and Career Readiness $(\alpha = 0.940)$. This confirms that the survey items consistently measured the intended constructs.

4.3 Composite Scores and Correlations

Composite mean scores revealed moderate perceptions of education quality $(M = 3.21)$, with slightly lower levels of technological integration $(M = 3.02)$ and career readiness $(M = 2.89)$. Pearson correlation analysis demonstrated strong positive relationships among the variables: Technological Integration was highly correlated with Education Quality ($r = 0.989$, $p < .001$) and Career Readiness ($r = 0.972$, $p < .001$), while Education Quality was strongly associated with Career Readiness ($r = 0.976$, $p < .001$). These findings indicate that students' exposure to technology is closely linked to their perception of instructional quality and their readiness for maritime careers.

4.4 Hypothesis Testing

All proposed hypotheses were supported at $p < .001$:

H1: Technological Integration significantly influences Education Quality.

H2: Education Quality significantly influences Career Readiness.

H3: Technological Integration significantly influences Career Readiness.

These results suggest that improving technological integration within maritime education could enhance both the perceived quality of education and students' readiness for digitally advanced maritime operations.

4.5 Discussion

Overall, the findings indicate that while students perceive their education quality positively, moderate exposure to technology and simulators may limit their preparedness for Industry 4.0 maritime careers. The strong correlations among technological integration, education quality, and career readiness highlight the critical role of technology-based learning in developing competent and confident maritime graduates. The lower career readiness scores suggest a need for more practical, hands-on, and simulation-based training to build confidence and technical competence.

4.6 Summary

In summary, Malaysian maritime students report moderate technological integration and education quality, with slightly lower career readiness. Reliability tests confirm consistent measurement, and correlation and hypothesis testing demonstrate strong interrelationships among the study variables. These results provide evidence that enhancing technological integration in maritime education can positively impact both educational effectiveness and career preparedness.

5. Significance and Impact

5.1 Significance of the Study

This research holds significant academic, industrial, and societal relevance within the context of Malaysia's evolving maritime landscape. Maritime education is at a pivotal stage where traditional seafaring training must adapt to rapid technological changes, automation, and sustainability demands. The study provides empirical evidence on

how technological transformation affects maritime education outcomes and career trajectories, contributing to both local and global maritime scholarship.

5.2 Impact of the Study

Educational Impact: The study provides valuable and actionable insights into the transformation and modernization of maritime education curricula in Malaysia, particularly in response to the increasing digitalization and technological advancement of the maritime industry. The integration of advanced maritime simulation technologies, virtual reality (VR) environments, interactive digital learning resources, and e-learning platforms can significantly enhance students' learning experiences by promoting practical engagement, experiential learning, and the development of essential technical competencies (Yusoff et al., 2024). These technological approaches also provide opportunities for students to experience realistic maritime operational scenarios, strengthen critical thinking and decision-making abilities, and develop greater confidence in handling complex navigational and shipboard situations. Furthermore, the findings emphasize the importance of moving beyond minimum compliance with the Standards of Training, Certification and Watchkeeping for Seafarers (STCW) Convention by adopting innovative, competency-based, and industry-responsive teaching methodologies. Maritime education institutions are therefore encouraged to continuously review and improve their curricula, strengthen the digital competencies of academic staff, and establish closer collaboration with maritime industry stakeholders to ensure that graduates possess the technical knowledge, adaptability, and operational readiness required for increasingly automated and digitally integrated maritime environments.

Industrial Impact: The global maritime industry continues to face significant challenges associated with the shortage of technically competent maritime officers, skilled seafarers, and qualified maritime managers capable of adapting to increasingly complex and technologically advanced maritime operations. By identifying the existing strengths, limitations, and competency gaps within maritime education and training systems, this study provides valuable insights into addressing workforce development challenges and improving the alignment between academic preparation and industry expectations. The findings highlight the importance of strengthening collaboration between maritime education and training institutions, shipping companies, port operators, and other maritime stakeholders to establish a more sustainable and industry-responsive talent development framework. Such collaboration can be achieved through structured industrial training programs, industry-led workshops, professional mentorship initiatives, apprenticeship opportunities, and the integration of real-world operational experiences into academic curricula. Furthermore, maritime employers can utilize the findings to identify essential technical, managerial, and digital competencies required for modern shipboard and shore-based operations, thereby facilitating more targeted recruitment, training, and professional development strategies. Strengthening these institutional and industrial partnerships is expected to improve graduates' operational readiness, technical proficiency, problem-solving abilities, and adaptability to emerging maritime technologies. Ultimately, these improvements can contribute to enhanced navigational safety, operational efficiency, workforce productivity, and organizational competitiveness while supporting the long-term sustainability and technological transformation of the maritime industry.

Social and Economic Impact: From a broader societal and economic perspective, this study contributes to Malaysia's long-term strategic objectives of strengthening maritime human capital development, enhancing workforce employability, and supporting sustainable growth within the national maritime sector. The development of highly skilled, technically competent, and technologically adaptable maritime graduates plays a crucial role in creating sustainable employment opportunities, improving career progression, and strengthening the availability of qualified professionals across various maritime-related industries. These graduates contribute directly to national economic development through their involvement in port management, shipping and logistics operations, vessel management, maritime transportation, offshore activities, and international trade. Furthermore, strengthening the alignment between maritime education and emerging industrial requirements can reduce existing skills mismatches, improve graduate employability, and enhance Malaysia's competitiveness as a regional maritime and logistics hub. As highlighted by UNCTAD (2023), investment in maritime infrastructure, human capital, and technological capabilities is important for strengthening maritime competitiveness and supporting economic development, particularly in developing economies. Beyond economic contributions, the study also emphasizes the social importance of developing a knowledgeable and professionally responsible maritime workforce capable of supporting safer, more efficient, and environmentally sustainable shipping operations. As the global maritime industry increasingly transitions toward decarbonization, alternative marine fuels, energy-efficient technologies, and environmentally responsible operational practices, maritime professionals must possess the competencies necessary to implement sustainable solutions and comply with evolving international environmental regulations. Consequently, strengthening maritime education through technology-driven and sustainability-oriented approaches can support

Malaysia's broader commitments to environmental protection, economic resilience, social mobility, and sustainable development while ensuring that its maritime workforce remains competitive in an increasingly interconnected global economy.

6. Discussion

6.1 Introduction

This study examined the relationships between technological integration, education quality, and career readiness among Malaysian maritime students. Data from 71 respondents revealed strong positive correlations among all constructs, supporting all research hypotheses. The discussion focuses on the three primary relationships investigated.

6.2 Technological Integration and Education Quality

Technological integration showed a very strong positive correlation with education quality ($r = 0.989, p < .001$). Students with greater exposure to simulators, ECDIS, radar/ARPA, and digital navigation tools reported higher perceptions of instructional quality. This supports Technology Acceptance and Integration Theory (TAIT) and Constructivist Learning Theory, which emphasise that technology-enhanced learning enables practical application of knowledge in simulated maritime environments. Item-level results indicated moderate technology exposure, suggesting that increased access to simulators and advanced digital tools could further enhance perceived education quality.

6.3 Education Quality and Career Readiness

Education quality was strongly associated with career readiness ($r = 0.976, p < .001$). Students who perceived their education as structured, relevant, and effectively delivered reported higher confidence in entering the digitalised maritime workforce. Moderate ratings on assessment relevance and teaching clarity highlight opportunities to better align curricula with real-world operational demands. This finding reinforces the importance of competency-based education, in line with STCW standards, for enhancing students' preparedness for maritime careers.

6.4 Technological Integration and Career Readiness

Technological integration also had a strong direct impact on career readiness ($r = 0.972, p < .001$). Even moderate exposure to simulator-based and digital navigation training significantly influenced students' confidence and operational preparedness. This suggests that increasing the frequency and realism of technology-driven training can substantially improve career readiness.

6.5 Implications

Theoretical: The findings validate TAIT and Constructivist Learning Theory in maritime education and demonstrate that education quality mediates the effect of technology on career readiness. Practical: Maritime institutions should invest in modern simulators, integrate scenario-based learning, and update curricula to reflect digital maritime operations. Educators should adopt blended learning approaches that combine theory, simulation, and real-world case studies. Policy: Regulatory bodies should standardise digital competency requirements and encourage industry-academia collaboration to provide students with practical exposure to modern vessels and smart ship technologies.

6.6 Limitations

The study used convenience sampling, limiting generalisability. Data were self-reported and cross-sectional, preventing assessment of long-term cause–effect relationships. The sample was limited to students, and results may differ for officers or cadets onboard vessels.

6.7 Conclusion

The study provides strong evidence that technological integration is central to improving education quality and career readiness in Malaysian maritime education. Enhancing access to simulation and digital training, aligning curricula with industry demands, and investing in modern maritime technologies can significantly prepare students for the evolving digital maritime sector. The findings offer practical guidance for educators, policymakers, and industry stakeholders seeking to strengthen maritime training and graduate employability.

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Conflict of Interest

The author(s) declare that there is no conflict of interest regarding the research, authorship, and publication of this article.

Author Contributions

Muhammad Adam Daniel Amran was involved in conceptualizing the study, developing the research methodology, and critically reviewing and refining the manuscript. Mohammed Ismail Russtam Suhrab provided supervision, guidance, and oversight throughout the research process.

Data Availability Statement

No publicly available data are associated with this study.

Ethics Statement

The author(s) have complied with all applicable research ethics requirements throughout the conduct of this study.

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