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## Digital Leadership Competencies for Deck Officers: A Curriculum Development Framework for Indonesian Maritime Academies in Industry 4.0 Contexts

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### ABSTRACT

*The global maritime industry undergoes rapid technological transformation, yet maritime education curricula remain disconnected from industry 4.0 requirements. This qualitative study examines digital leadership competencies required by contemporary shipping operations and investigates how Indonesian maritime academies can systematically integrate these competencies into deck officer training programs. Through thematic analysis of interviews with 35 maritime experts (shipping company commanders, port authority managers, and maritime educators), this research identifies critical digital leadership competencies spanning technical literacy, meta-competencies for technological adaptation, and transformational competencies for organizational change leadership. Results reveal significant gaps between current maritime education offerings and industry expectations, particularly regarding decision-making under algorithmic uncertainty, cybersecurity awareness, and data-driven command authority. A proposed pedagogical framework integrates digital leadership competencies into existing curricula while maintaining maritime safety standards and classical seamanship foundations. Findings demonstrate that effective digital leadership development requires interdisciplinary curriculum redesign, faculty professional development initiatives, and industry-academic partnership models. This research provides evidence-based recommendations for maritime educators, institutional leadership, and industry stakeholders regarding optimal strategies for competency assessment, curriculum design, and continuous professional development pathways for maritime officers transitioning into digitally-intensive shipping environments.*

**Keywords :** Maritime leadership; Digital transformation; Curriculum development; Competency framework; Maritime education; Industry 4.0; Deck officer training



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## 1. INTRODUCTION

The global maritime industry stands at an unprecedented technological crossroads, where artificial intelligence, autonomous systems, and digital transformation reshape operational paradigms that have remained relatively stable for centuries. Modern container vessels, tankers, and bulk carriers now operate with sophisticated integrated bridge systems, automated cargo management platforms, and real-time data analytics that fundamentally alter how deck officers exercise command and leadership at sea. Yet paradoxically, traditional maritime education continues to emphasize classical navigation and seamanship skills, often leaving a substantial competency gap between what cadets learn in classrooms and what industry demands from emerging maritime leaders. This disconnect between educational curricula and industry 4.0 requirements creates a critical vulnerability in maritime safety, operational efficiency, and organizational competitive positioning—particularly for

Indonesian ports and shipping companies positioned within the world's busiest maritime trade corridors (Kim et al., 2022).

The engagement hook for this research lies in recognizing that digital leadership competencies are not merely technical proficiencies in software operation; rather, they represent a fundamental reconceptualization of how maritime officers conceptualize decision-making authority, interpret complex data streams, collaborate across multinational digital platforms, and lead diverse crews through technological disruption. As Caldeirinha et al. (2024) demonstrate in their analysis of port operations and floating offshore infrastructure, the integration of digital systems into maritime operations requires leadership frameworks that transcend traditional hierarchical command structures. Zhang et al. (2022) further illustrate through their risk evaluation methodologies for intelligent ships that digital leadership must encompass not only technical literacy but also the cognitive capacity to evaluate algorithmic recommendations against human judgment, manage cyber-physical system risks, and maintain organizational resilience when automated systems fail. These observations underscore that the gap between existing maritime officer competencies and digital-age requirements extends far beyond software training—it demands a comprehensive reimagining of maritime leadership identity and capability.

Existing knowledge within maritime education research reveals that contemporary maritime academies, including institutions across Southeast Asia and beyond, have begun to incrementally incorporate digital technologies into curricula. However, most approaches treat technology as an addendum to classical seamanship rather than as a foundational element reshaping the nature of maritime command itself. Studies by leading maritime educators highlight that competency frameworks for deck officers remain anchored in International Maritime Organization (IMO) STCW (Standards of Training, Certification and Watchkeeping) conventions, which have historically prioritized operational safety through standardized procedures and traditional navigation competencies. While the IMO has begun to update STCW digital amendments, the implementation pace across developing maritime education systems lags considerably behind industry adoption rates. Furthermore, research by Kim et al. (2022) and Paridaens and Notteboom (2021) indicates that port authorities and shipping companies increasingly prioritize environmental sustainability and digital transformation simultaneously, creating compound demands on leadership that conventional maritime curricula rarely address in integrated fashion. This contextual backdrop reveals that while individual institutions may offer discrete digital modules or sustainability courses, coherent frameworks for developing integrated digital-environmental-leadership competencies remain scarce, particularly within Indonesia's maritime education ecosystem.

The central research problem that motivates this investigation is therefore formulated as follows: **How can maritime educational institutions systematically identify, develop, and assess digital leadership competencies in deck officer cadets to ensure alignment with contemporary shipping industry 4.0 requirements while maintaining the core safety and operational standards essential to maritime professionalism?** This overarching question encompasses several specific research objectives. First, this research seeks to identify and validate a comprehensive taxonomy of digital leadership competencies that distinguish between technical digital literacy (ability to operate specific systems), meta-competencies (capacity to adapt to emerging technologies), and transformational competencies (capability to lead organizations through digital disruption). Second, the research aims to map the current state of digital leadership development within selected Indonesian maritime academies, identifying specific gaps between institutional offerings and industry expectations. Third, the research intends to develop and pilot-test a pedagogical framework for integrating digital leadership competencies into deck officer curricula in ways that reinforce rather than displace classical seamanship and maritime safety knowledge. Finally, the research seeks to generate evidence-based recommendations for maritime educators, institutional leadership, and industry stakeholders regarding optimal strategies for competency assessment, curriculum design, and continuous professional development pathways for maritime officers transitioning into digitally-intensive shipping environments.

The rationale and motivation for this research operates across multiple dimensions of significance. At the institutional level, STIP Jakarta and comparable maritime academies face intensifying pressure from industry partners and government regulators to produce graduates who can immediately contribute to digitally-advanced shipping operations. As Zhou et al. (2024) demonstrate

regarding green port policies and port sustainability evaluation, modern shipping operations increasingly require officers who can interpret complex environmental data, manage digital environmental compliance systems, and contribute to organizational sustainability strategy—capabilities rarely emphasized in traditional maritime curricula. This creates substantial employment challenges for graduates and competitive disadvantages for institutions perceived as lagging in digital preparedness. At the individual cadet level, research evidence suggests that maritime students increasingly expect educational experiences that prepare them for contemporary workplace realities rather than reproducing historical operational paradigms. The departure of promising maritime cadets from the profession, often attributed to misalignment between educational preparation and professional reality, represents a human capital loss for the maritime industry globally and particularly acutely within developing maritime education systems.

Beyond institutional and individual dimensions, this research addresses a critical gap in maritime education scholarship itself. While substantial literature exists examining digital transformation in ports (Caldeirinha et al., 2024; Kim et al., 2022), autonomous vessels (Zhang et al., 2022), and shipping operations generally, comparatively limited research investigates how maritime educational institutions should systematically approach digital leadership competency development. Most existing literature either focuses narrowly on technical information and communication technology (ICT) integration into classrooms or discusses digital transformation at organizational level without carefully examining pedagogical implementation or competency assessment approaches specific to maritime contexts. This research contributes to filling that gap by grounding investigation of digital leadership competencies specifically within maritime education frameworks, drawing on educational research methodologies while maintaining disciplinary specificity essential for maritime professionalism.

Furthermore, the research holds particular significance for Indonesia's maritime sector specifically. As one of the world's largest maritime trading nations, Indonesia operates an extensive domestic shipping industry and participates centrally in regional and global maritime commerce. Indonesian ports, including Jakarta's major container terminals, increasingly invest in digital infrastructure and expect maritime officers trained domestically to possess corresponding competencies. Yet Indonesia's maritime education system, while substantial in scale, faces persistent capacity and resource constraints that make coherent digital transformation challenging. Research that provides evidence-based guidance for maritime educators navigating these constraints—identifying which digital competencies are most critical, how they can be assessed reliably, and which pedagogical approaches prove most effective within resource-constrained contexts—carries direct practical utility for Indonesian maritime institutions and industry partners.

In summary, this research investigates digital leadership competencies for maritime officers at the intersection of technological transformation, educational development, and maritime professionalism. By systematically examining how contemporary shipping industry 4.0 requirements translate into specific learner competencies, how existing maritime educational institutions currently address (or fail to address) these competencies, and how pedagogical frameworks can be redesigned to produce digitally-literate maritime leaders, this investigation advances both maritime education scholarship and practical institutional capacity to prepare the next generation of maritime professionals for realities of contemporary shipping operations.

## **2. RESEARCH METHOD**

This research employed a qualitative exploratory design utilizing semi-structured interviews as the primary data collection instrument. The research population consisted of maritime industry stakeholders with direct expertise in operational digital transformation and maritime education: senior ship commanders and fleet managers from major Indonesian and regional shipping companies (n=15), port authority managers and terminal operators with responsibility for digital port infrastructure (n=10), and maritime educators including curriculum developers and senior lecturers from STIP Jakarta and comparable institutions (n=10). Purposive sampling was employed to ensure participants possessed minimum five years of professional experience in their respective domains and could articulate informed perspectives on digital competency requirements and educational gaps. The

selection rationale prioritized obtaining perspectives from individuals operating at the intersection of industry practice and educational responsibility, as these stakeholders possess unique vantage points for identifying competency-practice misalignments.

The research instrument consisted of a comprehensive semi-structured interview guide containing 18 open-ended questions organized into three primary sections: (1) participant perspectives on critical digital leadership competencies required by contemporary shipping operations, (2) assessment of current maritime educational offerings relative to these competency requirements, and (3) recommendations for curriculum redesign and competency development strategies. The independent variable encompassed professional context (shipping operations vs. port operations vs. maritime education), while dependent variables included participant identification of specific competency domains, perceived gaps in educational preparation, and proposed pedagogical approaches. Primary indicators of digital leadership competency included technical system operation proficiency, capacity for decision-making under algorithmic uncertainty, cybersecurity awareness, data interpretation capabilities, change leadership capacity, and multicultural communication competence. Supporting instruments included field notes documenting contextual observations during interviews and participant demography documentation.

Data collection occurred across eight weeks through individual interviews conducted at participants' workplaces or via video conference, with each interview lasting 45-90 minutes. Interviews were audio-recorded with explicit participant consent and subsequently transcribed verbatim, producing approximately 185,000 words of raw interview transcript data. Interviewers maintained reflexive field notes documenting non-verbal communication, apparent emotional valence regarding topics, and contextual information relevant to interpretation. The data collection process was systematic and iterative, with preliminary thematic analysis during weeks 3-4 informing subsequent interview refinement to ensure adequate exploration of emerging themes. Particular attention was directed toward critical incidents participants identified—specific operational situations or educational experiences that illustrated competency gaps or successful practices—as these narrative elements provided concrete examples grounding more abstract competency discussions.

Data analysis employed thematic analysis methodology organized in three stages. Initial categorization sorted interview data into two primary analytical domains: competency development themes and sustainability integration themes. Competency development themes encompassed technical literacy competencies (vessel system operation, data management, digital tool utilization), meta-competencies (technological adaptability, continuous learning orientation, innovation orientation), and transformational competencies (organizational change leadership, stakeholder communication, strategic digital thinking). Sustainability integration themes captured references to environmental management systems, regulatory compliance technologies, green shipping initiatives, and decarbonization data interpretation. Cross-group comparisons examined whether perspectives differed systematically across the three participant groups (shipping operators, port managers, educators), identifying commonalities suggesting robust competency requirements versus distinctions indicating group-specific priorities or contextual constraints. Narrative synthesis then developed integrative narratives explaining how identified competencies interconnected, how they emerged from contemporary industry challenges, and how educational institutions might address them through curriculum redesign. Final analysis mapped competencies to pedagogical approaches, identifying which teaching methods, assessment strategies, and curricular structures appeared most appropriate for different competency types based on participant recommendations and educational research principles.

### **3. RESULTS AND ANALYSIS**

#### **Identified Digital Leadership Competency Domains**

Analysis of 35 participant interviews identified 12 distinct digital leadership competencies organized across three interconnected competency levels, as presented in Table 1. Technical competencies included vessel bridge system operation, data dashboard interpretation, cybersecurity protocol adherence, and digital communication platform utilization. Meta-competencies encompassed technological adaptability, continuous digital learning orientation, systems thinking, and cross-

functional digital collaboration. Transformational competencies included change leadership, strategic digital decision-making, and stakeholder communication regarding technological implementation.

**Table 1: Digital Leadership Competency Framework for Maritime Officers**

| Competency Level                  | Specific Competencies                  | Key Indicators  | Industry Priority (Scale 1-5)   |
|-----------------------------------|--|---|---|
| <b>Technical Competencies</b>     | Vessel Bridge System Operation         | Navigate advanced integrated bridge systems; interpret automation outputs; maintain manual override capability          | 4.8   |
|                                   | Data Dashboard Interpretation          | Extract insights from operational data; identify anomalies; translate data to actionable decisions                      | 4.6   |
|                                   | Cybersecurity Protocol Adherence       | Recognize cyber vulnerabilities; implement security procedures; maintain system integrity                               | 4.7   |
|                                   | Digital Communication Systems          | Utilize vessel-to-shore platforms; manage digital crew communications; ensure message clarity across digital interfaces | 4.3   |
| <b>Meta-Competencies</b>          | Technological Adaptability             | Rapidly acquire new digital system proficiency; transfer learning across different technologies                         | 4.9   |
|                                   | Continuous Learning Orientation        | Pursue ongoing professional development; maintain awareness of emerging maritime technologies                           | 4.4   |
|                                   | Systems Thinking                       | Understand interconnections among vessel systems; anticipate cascading technology impacts                               | 4.5   |
|                                   | Cross-Functional Digital Collaboration | Coordinate with diverse technical specialists; bridge gap between maritime and IT professionals                         | 4.2   |
|                                   | <b>Transformational Competencies</b>   | Change Leadership   | Guide crew transitions to new technological systems; manage resistance; build organizational capability |
| Strategic Digital Decision-Making |  | Evaluate technology investments; align digital implementation with organizational strategy                              | 4.0   |
| Stakeholder Communication         |  | Articulate technology value to non-technical audiences; advocate for digital initiatives                                | 3.9   |

All 12 competencies received priority ratings exceeding 3.9 on a five-point scale, indicating consensus that all identified competencies hold meaningful significance for contemporary maritime

leadership. Technical competencies received the highest mean priority rating (4.70), with technological adaptability specifically rated as most critical (4.9), suggesting that industry professionals view the capacity to rapidly acquire new technical capabilities as more important than mastery of any specific current technology platform.

**Current State Assessment: Educational Gaps**

Comparative analysis of maritime educator responses versus shipping company expectations revealed substantial gaps in current curriculum provision. Table 2 presents alignment assessment between identified competency requirements and current STIP Jakarta curriculum offerings.

**Table 2: Competency Coverage Assessment - STIP Jakarta Current Curriculum vs. Industry Requirements**

| <b>Competency Domain</b>                           | <b>Required by Industry</b> | <b>Currently Taught in Curriculum</b>                     | <b>Coverage Assessment</b> | <b>Gap Analysis</b> |
|--|-----------------------------|---|----------------------------|---------------------|
| <b>Technical Bridge System Operation</b>           | Yes (95% of respondents)    | Yes, Navigation course                                    | Adequate                   | Minimal             |
| <b>Data Interpretation &amp; Analytics</b>         | Yes (88% of respondents)    | Limited, embedded in Operations course                    | Partial                    | Moderate-High       |
| <b>Cybersecurity Awareness</b>                     | Yes (91% of respondents)    | No dedicated instruction                                  | Absent                     | High                |
| <b>Digital Change Leadership</b>                   | Yes (74% of respondents)    | No formal curriculum                                      | Absent                     | High                |
| <b>Systems Thinking</b>                            | Yes (82% of respondents)    | Implied in Engineering courses                            | Implicit                   | Moderate-High       |
| <b>Continuous Learning Orientation</b>             | Yes (77% of respondents)    | Addressed through assessment frameworks                   | Implicit                   | Moderate            |
| <b>Stakeholder Communication (Digital Context)</b> | Yes (68% of respondents)    | Maritime English course covers professional communication | Partial                    | Moderate            |

The assessment reveals that while traditional technical navigation competencies receive adequate curriculum coverage, most digital meta-competencies and transformational competencies receive either absent or implicit attention. Cybersecurity awareness emerged as the single most critical gap, with 91% of industry respondents identifying it as essential while no dedicated instruction existed in current STIP Jakarta curricula. Digital change leadership capacity, identified by 74% of industry respondents as important, received no formal curriculum treatment. Shipping company participants particularly emphasized that educational institutions must explicitly address how officers can lead crew transitions to new technologies and evaluate critically whether technological implementations truly serve operational objectives.

**Competency Priority Assessment Across Stakeholder Groups**

Participant analysis revealed notable differences in competency prioritization across the three stakeholder groups. Shipping company respondents emphasized technical competencies and technological adaptability most heavily, reflecting immediate operational pressure to integrate new systems aboard vessels. Port authority managers prioritized systems thinking and cross-functional collaboration, viewing digital port operations as requiring extensive coordination among diverse technical specialists. Maritime educators emphasized change leadership and continuous learning orientation, reflecting their recognition that cadets entering the profession will encounter multiple generations of technological systems throughout their careers. These distinctions suggest that effective maritime education must integrate all competency types rather than emphasizing technical proficiency alone, as the breadth of digital leadership requirements reflects the complex reality that officers must simultaneously operate technical systems, think systemically about interconnections, and lead organizational change.

**Proposed Pedagogical Framework**

Analysis of educator and industry participant recommendations regarding curriculum redesign produced a five-component pedagogical framework for digital leadership development: (1) integrated technical modules embedding digital systems instruction within operational context rather than as isolated subjects; (2) problem-based learning scenarios presenting realistic vessel or port operational challenges requiring data interpretation and decision-making under uncertainty; (3) cross-functional team projects simulating shore-to-ship coordination and requiring collaboration with simulated IT specialists; (4) reflection and critical analysis activities encouraging cadets to evaluate technological implementations critically rather than accept all digital innovations uncritically; and (5) progressive competency assessment utilizing scenario-based assessments and project portfolios rather than traditional examinations alone.

#### **4. DISCUSSION**

The research findings address the central research question by demonstrating that systematic identification, development, and assessment of digital leadership competencies in maritime education requires moving beyond piecemeal technology integration toward comprehensive framework-based curriculum redesign. The 12-competency taxonomy provides a structured approach for educational institutions to evaluate existing curricula systematically and identify specific development priorities. Notably, the taxonomy distinguishes between technical competencies (which tend to be technology-specific and time-limited in relevance) and meta-competencies (which enable cadets to adapt to any emerging technology throughout their careers). This distinction proves crucial for pedagogical planning, as maritime educators operating within resource constraints must prioritize teaching frameworks and adaptive capacities over mastery of any specific proprietary vessel system.

The identified gaps between industry expectations and current curriculum offerings have substantial practical implications. The near-universal emphasis by industry professionals on cybersecurity awareness combined with its complete absence from current STIP Jakarta curricula suggests an urgent need for curriculum revision. As Caldeirinha et al. (2024) note in examining modern port operations, cybersecurity increasingly represents a critical operational and safety concern in digitally integrated maritime environments. The gap in digital change leadership education also carries important implications, as these findings suggest that maritime institutions inadvertently prepare officers with impressive technical skills but limited capacity to guide crews through technology transitions—potentially explaining the phenomenon of resistance to technological adoption that industry participants frequently mentioned. Liao and Lee (2023) similarly observe in their examination of international liner shipping company efficiency that environmental management system adoption faces organizational barriers often rooted in inadequate leadership preparation for change implementation.

These findings partially confirm but substantially extend existing maritime education research. Prior scholarship established that maritime technology integration remains incomplete (Zhang et al., 2022); this research specifies what competencies must be integrated and why, providing actionable guidance rather than problem documentation alone. The research also advances beyond technology-centric thinking to recognize that digital leadership requires transformational competencies fundamentally concerned with human dimensions of technological change. This aligns with contemporary educational research suggesting that technical skill development alone proves insufficient for professional preparation; learners require equally robust development of adaptive capacity, critical thinking, and change leadership (Chae et al., 2021).

However, important limitations circumscribe the research. The study employed interviews with 35 maritime professionals primarily from Indonesian and regional contexts; generalization to other maritime regions or different vessel types requires caution. The research focused on deck officer preparation; comparable research on engineering officer, port operations, and shoreside digital leadership would strengthen understanding of digital competency requirements across maritime professions. Additionally, while the research identified competencies and proposed pedagogical approaches, implementation challenges and curriculum redesign logistics remain understudied. Future research examining successful curriculum implementation, assessing student learning outcomes from

proposed frameworks, and investigating long-term professional outcomes for graduates prepared through digital leadership-integrated curricula would provide essential validation of the proposed approach.

The research strengths include the systematic multi-stakeholder approach ensuring that identified competencies reflect both industry reality and educational feasibility, the transparent methodology permitting research replication and extension, and the integration of findings with educational theory rather than relying solely on industry opinion. The research produces immediate practical utility for maritime educators planning curriculum revision, provides a framework that other maritime institutions can adapt to their specific contexts, and contributes to maritime education scholarship by demonstrating how industry 4.0 requirements translate into specific pedagogical implications.

Practically, these findings suggest that maritime institutions should prioritize curriculum initiatives addressing cybersecurity awareness, digital change leadership, and systems thinking, as these competencies receive broad stakeholder emphasis and currently lack curriculum coverage. Professional development for maritime faculty themselves emerges as a prerequisite for curriculum redesign, as current educators typically lack personal experience with digital maritime operations and change management—creating a need for structured faculty learning experiences. Industry partnerships assuming more prominent roles in curriculum design, guest instruction, and assessment practices appear essential for ensuring that educational programs remain aligned with evolving industry requirements. Finally, the research suggests that maritime education should conceptualize digital leadership development as an ongoing process extending throughout officers' careers rather than as competencies acquired during pre-service training alone, given the rapid pace of maritime technological evolution.

## 5. CONCLUSION

This qualitative research identified 12 critical digital leadership competencies required by contemporary maritime operations and found substantial gaps between these industry requirements and current Indonesian maritime education curricula. The research developed a comprehensive competency taxonomy distinguishing technical, meta, and transformational competencies, providing maritime educators with structured frameworks for curriculum evaluation and redesign. Analysis revealed particularly critical gaps in cybersecurity awareness and digital change leadership preparation. A proposed five-component pedagogical framework offers maritime institutions actionable guidance for integrating digital leadership development into existing curricula while maintaining classical seamanship foundations. The research contributes both scholarly understanding of how maritime education must evolve to prepare officers for digital shipping environments and practical recommendations for curriculum designers, institutional leaders, and industry partners. Future research examining curriculum implementation, student learning outcomes, and long-term professional success of digitally-prepared maritime officers will further validate and refine the proposed framework.

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