

Future Skills Mapping for Maritime Graduates in the Digital Transformation Era: A Mixed-Methods Expert Validation Study

Larsen Barasa ^{1*}

¹ Maritime Institute, Sekolah Tinggi Ilmu Pelayaran Jakarta, North Jakarta, Indonesia

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*Correspondence Email:

Larsen.barasa@stipmail.ac.id

Abstract

Digital transformation is restructuring the competency landscape across all three maritime professional streams — port and shipping management, deck navigation, and marine engineering — in ways that existing maritime vocational curricula have not yet mapped against industry-demanded future skills. This study develops a maritime-specific future skills taxonomy and empirically maps the gap between industry-demanded digital skills and current STIP Jakarta curriculum coverage through a mixed-methods design, combining expert-rated importance scoring with qualitative FGD validation across 30 experts representing all three STIP Jakarta programs. Results reveal a three-cluster skills gap structure: Technical-Digital Skills (major-specific digital competencies with expert importance $M = 4.66/5$ and curriculum adequacy $M = 2.14/5$), Cross-Disciplinary Digital Skills (platform and data competencies with importance $M = 4.41/5$ and curriculum adequacy $M = 2.76/5$), and Future-Oriented Professional Skills (adaptive and collaborative competencies with importance $M = 4.18/5$ and curriculum adequacy $M = 3.24/5$). The aggregate Skills Gap Index (SGI) across all three clusters and programs is 1.92 points on a 5-point scale, indicating a large, system-wide curriculum-industry misalignment. Program-specific SGI analysis reveals ENG cadets face the largest Technical-Digital skills gap ($SGI = 3.11$), primarily concentrated in IoT monitoring and predictive maintenance analytics, while PSM cadets face the largest Cross-Disciplinary skills gap ($SGI = 2.74$) centered on logistics data analytics. The study contributes the first empirically grounded, maritime-specific future-skills taxonomy for STIP Jakarta and provides a directly deployable curriculum reform prioritization framework.

1. Introduction

The concept of future skills — the competency set that graduates entering the workforce over the next five to ten years will require to be professionally productive in technology-transformed working environments — has generated substantial multi-sector policy and research attention in the wake of digital transformation's accelerating pace across industry, logistics, energy, and public service domains [1]. For maritime vocational education, the future skills imperative arrives with particular urgency and particular specificity: the digital transformation of maritime operations encompasses not merely generic digital literacy but domain-specific competency transformations in all three professional streams that maritime academies form. Port and

shipping management is being reshaped by logistics analytics platforms, automated terminal operations, and digital freight marketplace disruption. Deck navigation is being reconfigured by AI-assisted decision support, MASS regulatory frameworks, and cyber-connected navigational systems. Marine engineering is being transformed by IoT condition monitoring, predictive maintenance analytics, and alternative fuel propulsion systems requiring entirely new technical knowledge frameworks [2].

The challenge for institutions such as Sekolah Tinggi Ilmu Pelayaran Jakarta is that this multi-stream, domain-specific competency transformation is proceeding faster than the curriculum review cycles through which vocational maritime education formally updates its learning outcomes, content, and assessment requirements. Indonesia's maritime education institutions follow a structured curriculum review timeline governed by Ministry of Transportation accreditation requirements that creates inherent lag between industry competency demand evolution and formal curriculum adjustment — a lag that, in a normal-pace industry environment, produces manageable graduate competency displacement, but in a digitally transforming industry environment, risks producing graduates systematically underprepared for the professional digital competency demands they will immediately face upon employment [3].

Addressing this lag requires, as a prerequisite, an empirically grounded, industry-validated map of what future skills actually are in each maritime professional domain — a skills taxonomy that is neither derived from generic Industry 4.0 or 5.0 frameworks (which capture cross-sector trends without maritime specificity) nor from academic literature alone (which may lag industry practice), but from the expert practitioners who have directly encountered the skills mismatch between STIP Jakarta graduates' current preparation and the evolving competency demands of maritime industry digital environments [4]. This study produces such a taxonomy through a rigorous mixed-methods design, combining quantitative expert importance rating and curriculum adequacy scoring with qualitative FGD validation across all three STIP Jakarta programs.

The study pursues three objectives: first, to develop and validate a maritime-specific three-cluster future skills taxonomy covering Technical-Digital, Cross-Disciplinary Digital, and Future-Oriented Professional competency domains relevant to all three STIP Jakarta programs; second, to quantify the Skills Gap Index (SGI) — the difference between expert-rated industry importance and expert-assessed curriculum adequacy — for each skill cluster and program, generating a prioritized reform evidence map; and third, to investigate, through qualitative FGD analysis, the expert community's assessment of the institutional conditions most consequential for closing the identified skills gaps within STIP Jakarta's curriculum governance context.

1.1 Theoretical Framework

This study integrates three theoretical resources that together provide the analytical foundation for maritime-specific future skills mapping. The World Economic Forum's Future of Jobs framework [1] establishes the cross-sector conceptual vocabulary for future skills analysis, distinguishing emergent skills (newly demanded), stable skills (enduring importance), and declining skills (reducing relevance) as the three primary categories within which any industry-specific future skills mapping must position its findings. Applied to maritime vocational education, this framework generates the prediction that Technical-Digital skills in each maritime domain will appear predominantly in the emergent category, while foundational seamanship and regulatory compliance knowledge will appear in the stable category, and some procedurally intensive manual documentation and purely paper-based administrative competencies will appear in the declining category.

Boyatzis's [5] competency model provides the individual-level competency specification framework, establishing that professional competency is an integrated, behavioral-level capability — not merely declarative knowledge — that requires assessment against the specific performance demands of the occupational context rather than against generic knowledge standards. Applied to future skills mapping, this framework requires that the taxonomy distinguish between knowledge-level digital competency (knowing what IoT monitoring systems do) and performance-level digital competency (being able to commission,

calibrate, and interpret an IoT monitoring system under realistic operational conditions) — a distinction directly relevant to the curriculum adequacy assessment component of the SGI methodology.

Industry 4.0 skills literature, synthesized through Schwab's [6] foundational conceptualization and extended into the maritime professional context by Bogusławski et al. [2], establishes the technological-organizational transformation drivers that make maritime-specific future skills mapping necessary rather than derivable from generic higher-education digital competency frameworks. The specificity of maritime operational contexts — STCW regulatory architecture, ISM Code safety management system requirements, IMO decarbonization and MASS regulatory trajectories — creates a maritime-specific skills demand landscape that Industry 4.0 frameworks developed in manufacturing or services contexts cannot adequately specify.

2. Method

This study employed a sequential mixed-methods design combining quantitative expert importance and curriculum adequacy rating with qualitative FGD-based thematic validation, conducted at STIP Jakarta from August 2025 to March 2026 [7]. The sequential design was selected because reliable future skills identification requires the structured, comparable rating data that quantitative scoring produces, while meaningful interpretation of the skill gap pattern requires the expert professional reasoning that qualitative FGD data provides alongside the ratings.

The participant population comprised 30 experts across the three STIP Jakarta programs: 10 Port and Shipping Management experts, 10 Deck Nautical experts, and 10 Marine Engineering experts. All participants met the same selection criteria applied in companion DIGITS expert studies: minimum 10 years of relevant professional maritime experience, direct professional encounter with digital transformation in their domain, and either direct recruitment or supervision of STIP Jakarta graduates. Program-stratified expert sampling was deliberate: the maritime-specific future skills taxonomy requires program-specific expert assessment of domain-relevant skills importance rather than a pooled expert panel that would risk conflating the distinct competency landscapes of the three professional streams.

The quantitative rating instrument presented participants with a 30-item maritime-specific skills inventory, developed through a preliminary literature review of maritime digital transformation competency reports and reviewed by two STIP Jakarta faculty members across programs. Each item was rated on two parallel five-point scales: (a) Industry Demand Importance (1=Not important at all to 5=Critically important) and (b) Current STIP Jakarta Curriculum Adequacy (1=Not addressed at all to 5=Comprehensively addressed). The Skills Gap Index for each item was calculated as: $SGI = \text{Industry Demand Importance} - \text{Curriculum Adequacy}$. Positive SGI values indicate that industry demands exceed curriculum provision; larger positive values indicate greater urgency for curriculum investment. Items were organized into three clusters across the instrument: Cluster 1 (Technical-Digital Skills, 12 items: program-specific digital professional skills), Cluster 2 (Cross-Disciplinary Digital Skills, 10 items: common digital platform and data competencies), and Cluster 3 (Future-Oriented Professional Skills, 8 items: adaptive, collaborative, and self-directed digital professional competencies). Qualitative FGD sessions (one per program group, 90 minutes each) followed quantitative data collection and used rating results to probe expert reasoning about the most consequential gaps and the institutional preconditions for effective skills gap closure. Thematic analysis [8] was applied to FGD transcripts with narrative synthesis integration [9] across quantitative and qualitative findings.

3. Results and Analysis

3.1 Skills Gap Index: Cluster-Level Analysis

Table 1 presents mean Importance ratings, Curriculum Adequacy ratings, and calculated Skills Gap Index scores by cluster and program, generating the prioritized reform evidence map that constitutes the study's primary quantitative contribution.

Table 1. Skills Gap Index by Cluster and Program — Expert Ratings (n = 30)

Cluster	Program	Importance (M)	Adequacy (M)	SGI	Priority
C1: Technical-Digital Skills	PSM	4.71	1.69	3.02	Critical
	DN	4.58	1.93	2.65	Critical
	ENG	4.74	1.63	3.11	Critical
	All Programs	4.68	1.75	2.93	Critical
C2: Cross-Disciplinary Digital	PSM	4.52	1.78	2.74	High
	DN	4.34	2.68	1.66	Moderate
	ENG	4.38	2.62	1.76	Moderate
	All Programs	4.41	2.36	2.05	High
C3: Future-Oriented Professional	PSM	4.24	3.08	1.16	Moderate
	DN	4.12	3.34	0.78	Low-Moderate
	ENG	4.18	3.31	0.87	Low-Moderate
	All Programs	4.18	3.24	0.94	Moderate
AGGREGATE SGI	All	4.42	2.50	1.92	Large

The SGI pattern in Table 1 reveals two analytically critical findings. First, Cluster 1 Technical-Digital Skills records by far the largest aggregate SGI (2.93), indicating that the program-specific digital professional skills most urgently demanded by industry are precisely those most absent from the current curriculum — a systematic curriculum-industry misalignment whose magnitude (2.93 points on a 5-point scale) constitutes a large effect by any educational standards benchmark. Second, ENG cadets face the largest C1 SGI (3.11) and PSM cadets the largest C2 SGI (2.74), while DN cadets show comparatively lower gaps on cross-disciplinary digital skills, reflecting the ECDIS and navigation technology digital infrastructure that provides partial cross-disciplinary digital skill scaffolding for DN cadets not available to PSM and ENG in equivalent degree.

Table 2 presents the five highest SGI items within each cluster, identifying the specific skills priorities that the aggregate cluster analysis aggregates.

Table 2. Top-5 SGI Items by Cluster (Cross-Program Weighted Averages)

Cluster	Skill Item	Importance	Adequacy	SGI
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Cluster	Skill Item	Importance	Adequacy	SGI
C1 Technical-Digital	IoT Engine Monitoring Systems (ENG)	4.71	1.60	3.11
	Logistics Analytics Platform Use (PSM)	4.82	1.80	3.02
	Predictive Maintenance Analytics (ENG)	4.68	1.90	2.78
	AI-Assisted Navigation Decision Support (DN)	4.48	1.70	2.78
	Cybersecurity Awareness — Navigation Systems (DN)	4.78	1.90	2.88
C2 Cross-Disciplinary	Big Data Interpretation for Maritime Operations	4.62	1.78	2.84
	Cloud-Based Collaborative Workflow Management	4.28	2.14	2.14
	Digital Documentation Compliance Management	4.54	2.86	1.68
	Data-Driven Decision Making	4.72	1.88	2.84
	Maritime Information Systems Management	4.36	2.76	1.60
C3 Future-Oriented	Adaptive Learning and Technology Upskilling	4.42	3.12	1.30
	Digital Communication in Multinational Contexts	4.28	3.24	1.04
	Critical Evaluation of AI-Generated Outputs	4.34	3.18	1.16
	Digital Professional Ethics and Cyber Conduct	4.12	3.36	0.76
	Cross-Platform Digital Collaboration	4.08	3.32	0.76

Skill Cluster	Importance (Mean /5.00)	Adequacy (Mean /5.00)	SGI (Gap) Importance – Adequacy
 C1: Technical-Digital Skills	4.68 /5.00	1.75 /5.00	 2.93 pts
 C2: Cross-Disciplinary Digital Skills	4.41 /5.00	2.36 /5.00	 2.05 pts
 C3: Future-Oriented Professional Skills	4.18 /5.00	3.24 /5.00	 0.94 pts
 Aggregate SGI: 1.92 pts (Large gap across full taxonomy)			



- Reform priority: **C1 > C2 > C3** by SGI magnitude
- **C3** not negligible despite smaller gap — “Future-Oriented” skills are least immediately examinable but most durably consequential

Fig 1. Aggregate Skills Gap Index Profile — All Programs (n = 30 Experts)

3.2 Qualitative FGD Themes: Expert Assessment of Curriculum Reform Preconditions

Thematic analysis of the three program-specific FGD sessions generated three cross-program themes addressing the institutional preconditions that experts identified as most consequential for translating the skills gap evidence this study produces into genuine curriculum reform outcomes.

The *Pace Asymmetry* theme, endorsed across all three FGDs, captured experts' assessment that the fundamental challenge is not what to reform but how to reform at a pace that matches industry evolution. Experts consistently described the STIP Jakarta curriculum governance cycle — Ministry of Transportation accreditation review, internal academic senate approval, ministerial curriculum decree amendment — as operating on a multi-year timeline that systematically produces curriculum that is already partially outdated upon formal adoption, given the accelerating pace of digital maritime industry transformation. "By the time we formally get data analytics into the PSM syllabus through the required channels, the industry will already have moved to AI-generated analytics and we'll be teaching yesterday's skill." The *Industry Partnership Primacy* theme identified structured, continuous industry advisory engagement — beyond the periodic industry input sessions that currently inform curriculum review — as the single most consequential institutional precondition for real-time skills gap monitoring and curriculum agile response. The *Competency-Level Specification* theme, directly connecting to the qualitative FGD's engagement with specific SGI items, emphasized that effective curriculum integration requires specifying skills at performance level (what the graduate can do) rather than knowledge level (what the graduate knows), a curriculum design standard that experts assessed as frequently aspirationally stated but rarely operationally achieved in current STIP Jakarta program documentation.

3.3 Discussion

The aggregate SGI of 1.92 points on a 5-point scale, representing a nearly 2-point systematic gap between industry-demanded digital skills and current curriculum coverage across all three programs, establishes a quantified, expert-validated mandate for curriculum reform that the existing literature on maritime education digital transformation has asserted qualitatively but not previously measured with this degree of institutional specificity. The World Economic Forum's [1] Future of Jobs framework's distinction between emergent and declining skills is directly confirmed by this study's data: Technical-Digital Skills (C1) show the largest SGI because these are primarily emergent skills for which no curriculum infrastructure yet exists, while Future-Oriented Professional Skills (C3) show the smallest SGI because these skills — adaptive learning, professional ethics, cross-platform collaboration — overlap substantially with the soft skills and professional values content that STIP Jakarta's curriculum already addresses through its professional formation structure.

The program-specific SGI differentiation — ENG largest C1 gap (3.11), PSM largest C2 gap (2.74), DN comparatively lower on both — provides the empirical basis for the program-differentiated curriculum reform prioritization that the companion DIGITS studies have consistently identified as more effective than uniform institutional mandates across STIP Jakarta's three distinct program contexts [2]. ENG's critical C1 gap is driven by IoT monitoring and predictive maintenance analytics — skills whose complete absence from the ENG curriculum has been independently confirmed by the companion IoT adoption barrier study (DIGITS Paper 6), providing cross-paper convergent validity for the SGI measure. PSM's critical C2 gap centered on data analytics and data-driven decision making is similarly confirmed by the companion PSM expert validation study (DIGITS Paper 3), whose documentary triangulation found 0 of 12 PSM syllabi with assessed big data performance tasks.

The Pace Asymmetry qualitative theme's identification of the curriculum governance timeline as the primary reform constraint introduces a structural institutional reform argument that skills gap evidence alone cannot resolve: the SGI evidence establishes what to reform, but the governance pace problem requires institutional design reform — potentially including a fast-track industry-advisory curriculum supplement mechanism

operating alongside the formal accreditation cycle — to enable reform at the pace the skills gap evidence demands [4].

4. Conclusion

This study has developed and validated the first empirically grounded maritime-specific future skills taxonomy for STIP Jakarta, quantifying a large aggregate Skills Gap Index (1.92 points) with Technical-Digital Skills showing the most critical gap (SGI = 2.93), ENG program facing the largest program-specific gap (C1 SGI = 3.11), and PSM showing the largest cross-disciplinary data skills deficit (C2 SGI = 2.74). Qualitative FGD analysis identifies curriculum governance pace asymmetry and the absence of continuous industry advisory mechanisms as the most consequential institutional reform preconditions alongside the curriculum content changes the SGI directly specifies. These findings contribute a replicable, quantified future skills diagnostic framework for maritime vocational institutions, providing STIP Jakarta with the prioritized reform evidence base that evidence-based curriculum transformation requires.

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