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Collaborations Between Institutions and Industry in Naval Deck Engineering (Enhancing Sustainability in Maritime Education)

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Abstract: This study aims to examine how sustainability practices are integrated into naval deck engineering curricula and how industry-academia collaborations influence students' readiness for the maritime sector's green transition. Although sustainability is increasingly mandated by international maritime regulations — including the IMO's EEXI, CII, and the EU Emissions Trading System — no prior qualitative study has systematically assessed the integration gap from the simultaneous perspectives of industry experts, lecturers, and graduates within Indonesian naval deck engineering programs, representing the specific research gap this study addresses. A qualitative case study design was employed, with data collected through semi-structured interviews and focus group discussions with 30 participants: 5 maritime industry experts, 12 naval deck engineering lecturers, and 13 recent graduates from Indonesian maritime polytechnic institutions. Data were analyzed through a six-phase thematic analysis procedure with intercoder verification (Cohen's Kappa $\kappa = 0.83$) and validated through source triangulation and member checking. Three overarching themes emerged: curriculum integration gaps, technology content deficits, and insufficient industry collaboration depth. The study's principal scientific contribution is the demonstration that the sustainability education gap in Indonesian naval deck engineering is driven by a structural curriculum governance problem — the absence of formal industry co-design mechanisms — rather than by instructor knowledge deficits or student motivation issues, a finding that reorients the reform agenda from content addition to governance restructuring. Findings provide actionable recommendations for maritime polytechnics, the Ministry of Transportation, and IMO maritime education stakeholders.

Keywords: Maritime Education, Sustainability, Industry Collaboration, Green Technologies, Naval Deck Engineering

INTRODUCTION

The Maritime Sustainability Imperative and Its Educational Consequences

The global maritime industry stands at an inflection point. The International Maritime Organization's EEXI and Carbon Intensity Indicator regulations, alongside the EU Emissions Trading System, have established legally binding decarbonization targets that fundamentally reshape the operational requirements of naval deck engineering (de la Peña Zarzuelo et al., 2020; Liao & Lee, 2023). Alternative fuel propulsion — including liquefied natural gas, methanol, ammonia, and hydrogen — is transitioning from experimental to operational across the global merchant fleet, creating an urgent demand for graduates who can manage these systems safely and efficiently. By 2030, approximately 30 percent of the global merchant fleet will operate on alternative fuels, yet fewer than 15 percent of maritime institutions offer substantive green technology instruction (Kim et al., 2022). This workforce preparation gap has direct implications for maritime safety, operational compliance, and the global shipping industry's ability to meet its decarbonization commitments.

In Indonesia — one of the world's largest seafarer-supplying nations, with approximately 234,000 certified seafarers and a maritime sector contributing 3.8 percent of national GDP — the quality of naval deck engineering education determines both the country's competitive position in global maritime labor markets and the environmental safety of Indonesia's own archipelagic sea transportation network (Wulandari & Cahyadi, 2025; Wahyudi et al., 2025). Indonesian maritime polytechnics operate within a certification-aligned curriculum framework governed by STCW Convention standards. While this framework establishes minimum competency standards, it does not dynamically incorporate emerging sustainability competency demands at the pace that the maritime regulatory environment requires (Komaro et al., 2022; Daryono et al., 2023).

The Research Gap and State of the Art

Existing maritime sustainability education research has addressed individual dimensions of this challenge in partial ways. Ghosh et al. (2014) argued that authentic seafarer assessment requires engagement with real operational contexts beyond STCW standards — a finding established a decade ago that remains unimplemented in most Indonesian maritime curricula. Sharma et al. (2019) examined the STCW competence framework's inadequacy for autonomous shipping, demonstrating that certification frameworks systematically lag industry technological evolution. Afinowi and Nhamo (2025) mapped coastal and marine research trends through bibliometric analysis, confirming that sustainability education in the maritime domain remains underrepresented in the academic literature relative to its operational urgency. Plaza-Hernández et al. (2021), examining IoT integration in maritime industry, established that the technological sophistication of maritime operations has accelerated beyond what existing educational infrastructure tracks.

However, no prior study has simultaneously examined the perspectives of industry experts, academic lecturers, and recent graduates on sustainability curriculum integration within Indonesian naval deck engineering programs — the multi-stakeholder qualitative design that can reveal where the competency gap is largest, why it persists structurally, and what institutional mechanisms can address it. Prior studies address either curriculum content (what is taught) or industry requirements (what is needed) but not the governance mechanisms (how curricula connect to industry) that determine whether alignment is sustained. Hattingh et al. (2022), examining aviation — a parallel safety-critical vocational domain — found that instructors' limited understanding of competency-based assessment had direct safety implications, establishing the principle that the gap between instructors' and practitioners' competency models is itself a safety risk. Suyetno et al. (2024), examining industry involvement in Indonesian vocational curriculum reform, found that genuine industry co-design — not formal consultative committee structures — is the variable that determines curriculum alignment with operational requirements. This study applies these analytical frameworks to Indonesian naval deck engineering for the first time.

Research Questions and Objectives

This study addresses three research questions: (RQ1) How effectively is sustainability integrated into naval deck engineering curricula in Indonesian maritime polytechnics, as perceived by experts, lecturers, and graduates? (RQ2) How does industry collaboration influence student readiness for maritime sustainability challenges, and what structural conditions enable or constrain effective collaboration? (RQ3) What curriculum governance reforms are necessary to achieve sustained alignment between naval deck engineering education and maritime industry sustainability demands?

The study pursues three corresponding objectives: to assess the extent and depth of sustainability integration in naval deck engineering curricula through multi-stakeholder qualitative analysis; to examine the structural conditions under which industry-academia collaboration produces meaningful student readiness outcomes; and to generate evidence-based recommendations for curriculum governance reform that are implementable within Indonesia's maritime education policy context.

Literature Review

Sustainability Integration in Maritime Vocational Education

The integration of sustainability into maritime vocational curricula represents a specific instance of the broader challenge of keeping competency-based education frameworks aligned with rapidly evolving industry operational demands. Wahyudi et al. (2025), examining university-industry partnership effectiveness in Indonesian vocational education, confirmed that adaptability and continuous improvement — rather than formal partnership structures — drive successful curriculum alignment. This finding reframes the sustainability curriculum gap from a content problem to a governance problem: the issue is not that sustainability topics are unknown to maritime educators but that the institutional mechanisms for continuously updating curricula to reflect industry regulatory changes are absent or inadequate. Nidhom et al. (2025), in a systematic review of vocational teacher professional education, established that the interaction among professional competence, institutional support, and working conditions determines whether vocational educators can develop and maintain industry-current technical knowledge — a tripartite condition that maritime polytechnic systems must deliberately design rather than assume.

Othman et al. (2025), reviewing digitalisation challenges in TVET institutions, confirmed that technology integration in vocational education requires coordinated investment in faculty capacity, curriculum redesign, and governance frameworks simultaneously — a finding applicable to green technology integration in maritime education. Mutohhari et al. (2025) documented critically low green skills maturity levels among Indonesian vocational teachers, establishing an empirical baseline for the faculty development gap that directly affects sustainability instruction quality in maritime programs. Widaningsih et al. (2025), mapping technical competency needs for TVET teachers in the Industry 4.0 era, confirmed that digital and green technology monitoring competencies represent the largest systemic gap among Indonesian vocational educators.

Industry-Academia Collaboration and Competency Development

The relationship between industry-academia collaboration quality and graduate competency outcomes is well-established across vocational education contexts. Oroh et al. (2023), analyzing student performance criteria based on industry needs in Indonesian vocational education, found that assessment context significantly influences competency development — with students in large-industry placements achieving substantially higher capability scores than those in small industries. This finding establishes that the quality of industry engagement, not merely its presence, determines educational outcomes. Daryono et al. (2024), developing a competency framework for engineering graduates from construction industry perspectives, demonstrated that industry-grounded competency frameworks provide substantially stronger curricular foundations than institution-designed frameworks — an analytical principle directly applicable to naval deck engineering sustainability competency specification. Song and Xu (2024), examining vocational education expansion in China, found that massification of technical training produces certification without genuine professional capability when systemic governance conditions are absent — a cautionary framework for Indonesian maritime education where enrollment growth has outpaced faculty sustainability competency development.

Ardiyanto et al. (2023), assessing Indonesian vocational students' comprehension of safety-relevant technical content, found that contextual familiarity and repeated experiential exposure are essential for developing reliable operational competence — establishing the learning science basis for why practical hands-on sustainability training is necessary rather than supplementary. Hattingh et al. (2022), examining aviation competency-based education, confirmed that instructor understanding of competency frameworks is a critical safety variable — establishing that faculty professional development is not merely a quality improvement measure but an operational safety imperative in safety-critical maritime education. Gerber and Crafford (2025), documenting workforce capability deficits arising from inadequate training infrastructure investment, established that systemic institutional intervention — rather than isolated instructional improvements — is the necessary response scale for structural competency gaps.

Maritime Regulatory Environment and Curriculum Response

The IMO's 2020 EEXI and CII frameworks, alongside the EU ETS maritime extension, have created an unprecedented regulatory environment that operationally mandates sustainability competency at a pace that maritime education systems have not matched (de la Peña Zarzuelo et al., 2020; Sharma et al., 2019). Afinowi and Nhamo (2025) documented through bibliometric analysis that sustainability research in maritime contexts has accelerated significantly since 2018 — confirming that regulatory pressure is generating scholarly attention but that educational system response lags both regulatory and scholarly development. Young (1995) established the foundational challenge in maritime education governance: STCW framework revisions occur through multi-year international consensus processes that cannot track the pace of industry technological change — a structural misalignment that generates systematic curriculum obsolescence in precisely the domains where regulatory change is fastest. Plaza-Hernández et al. (2021), examining IoT technology integration in maritime operations, demonstrated that operational technologies entering maritime practice routinely precede their incorporation into maritime education curricula by three to five years — a technology adoption lag with direct safety and compliance implications.

Aminah et al. (2025), demonstrating that formal outcome-based curriculum alignment frameworks can maintain systematic correspondence between program outcomes and instructional practices, provide a methodological model for how maritime sustainability competencies could be formally inscribed within program-level outcome specifications — closing the curriculum update lag through governance design rather than requiring STCW framework revision.

RESEARCH METHOD

Research Design

This study employs a qualitative case study design (Creswell & Poth, 2018; Merriam & Tisdell, 2016), examining sustainability integration and industry collaboration in Indonesian naval deck engineering programs as a bounded institutional case. The qualitative design was selected because the research questions concern governance processes, collaboration dynamics, and competency development experiences — phenomena requiring interpretive, contextually grounded analysis rather than quantitative measurement. The structured evaluation instruments (Tables 1–5) serve as supporting data providing cross-group triangulation indicators; they are not the primary analytical output. The primary analytical outputs are the three themes generated through thematic analysis of interview transcripts.

Participants and Purposive Sampling

Participants were selected through purposive criterion sampling to ensure positional authority and experiential grounding relevant to the research questions. The total sample of 30 participants comprises three groups:

Maritime Industry Experts (n=5): Inclusion criteria required minimum 15 years of operational or managerial experience in shipping, port management, or maritime industry human resources, with documented engagement in green technology operations or sustainability regulatory compliance. Participants represented senior officers in major Indonesian shipping companies, port management corporations, and maritime classification society representatives.

Naval Deck Engineering Lecturers (n=12): Inclusion criteria required active teaching responsibilities in naval deck engineering programs with minimum three years of maritime vocational instruction experience. Participants taught across propulsion systems, environmental compliance, and maritime safety subjects at three Indonesian maritime polytechnics.

Graduates (n=13): Inclusion criteria required completion of a naval deck engineering program within the preceding three years and minimum six months of professional maritime employment.

Table A. Participant Characteristics

Group	n	Core Qualification	Experience Range
Maritime Industry Experts	5	Min. 15 yrs maritime industry; green tech/sustainability role	16–31 years
Lecturers	12	Min. 3 yrs naval deck engineering instruction	4–22 years
Graduates	13	Naval deck engineering program; min. 6 months employment	6–30 months post-graduation
Total	**30**		

Data Collection

Semi-structured interviews were conducted face-to-face with expert and lecturer participants and via Zoom with graduate participants (due to distribution across vessels and port locations). All sessions lasted 60 to 90 minutes, were audio-recorded with written informed consent, and were transcribed verbatim within one week. An interview protocol addressed the three research question domains: sustainability curriculum coverage and depth; industry collaboration mechanisms and their practical effects on student preparedness; and participants' assessments of the most critical gaps and highest-priority reforms. Supporting structured evaluation instruments (10-point Likert-type scales on five sustainability indicators) were administered within each interview session and analyzed as triangulating descriptive data.

Thematic Analysis Procedure

Interview data underwent a six-phase thematic analysis following Braun and Clarke (2006). **Phase 1 (Familiarization):** All 30 transcripts were read twice, with researcher memos on emerging patterns. **Phase 2 (Open Coding):** Line-by-line coding in NVivo 14 generated 183 initial codes. **Phase 3 (Focused Coding):** Initial codes were grouped into 16 sub-categories, consolidated into three overarching themes: curriculum integration gaps, technology content deficits, and insufficient industry collaboration depth. **Phase 4 (Theme Review):** Themes were validated against the full dataset. **Phase 5 (Theme Definition):** Each theme received a precise analytical definition. **Phase 6 (Triangulation):** Interview themes were cross-referenced with structured evaluation scores and supplementary curriculum document analysis. A second independent coder coded 25 percent of transcripts; Cohen's Kappa was calculated at $\kappa = 0.83$, indicating strong intercoder agreement (Landis & Koch, 1977). Member checking was conducted with two participants per stakeholder group who reviewed and confirmed preliminary theme summaries.

Research Validity

Three procedures strengthened interpretive validity: **Source triangulation** cross-referenced interview findings with the supporting Likert-scale evaluation data and institutional curriculum documentation. **Member checking** with six participants (two per group) confirmed that preliminary theme summaries accurately represented participants' accounts. **Reflexive journaling** maintained throughout the analysis documented researcher positionality and interpretive decisions.

RESULTS AND DISCUSSION

The thematic analysis generated three overarching themes corresponding to the three research questions: curriculum integration gaps, technology content deficits, and insufficient industry collaboration depth. The following presentation integrates findings with theoretical interpretation, prior study comparison, and practical implications following the mandatory analytical structure: Finding → Interpretation → Theory → Implication.

Theme 1: Curriculum Integration Gaps

Finding: Sustainability topics are present in naval deck engineering curricula but are delivered at a foundational theoretical level that does not prepare graduates for the operational sustainability demands of contemporary maritime employment. Structured evaluation scores for curriculum alignment averaged 7.67 across all groups, with expert scores (8.0) consistently higher than graduate scores (8.0 for theoretical adequacy but lower on practical application sub-items). The qualitative data reveal a theory-practice gap that the overall score does not capture.

One graduate with 14 months of professional experience as a third officer stated:

"In class, we covered energy efficiency management plans and emissions monitoring — I understood the concepts well enough to pass examinations. But when I was on board and responsible for operating the exhaust gas cleaning system during a port entry under the EU ETS zone, I had no practical reference for that specific technology. The regulation and the system existed; my training had not connected them."

A lecturer with nine years of instruction in propulsion systems confirmed the structural source of this gap:

"The curriculum lists the learning outcomes we need to cover, and sustainability topics are there. But the assessment asks students to recall or explain concepts — it does not require them to demonstrate operation of actual systems. We evaluate theoretical understanding because that is what the certification examination assesses. The practical dimension is implicit, not evaluated, and therefore not taught with the same rigor."

Supporting scores for Table 1 (curriculum alignment) and Table 3 (competency development) confirm this pattern: expert scores for conceptual alignment (8.0) are consistently higher than graduate scores for practical application readiness (averaging 7.0 on application sub-items), with the gap widest on indicators relating to alternative fuel systems and emissions control operation.

Interpretation: The curriculum integration gap is not a content problem — sustainability topics are present in syllabi — but an assessment architecture problem. When certification examinations assess declarative knowledge rather than operational performance, educators are structurally incentivized to teach for examination recall rather than for operational application. Graduates who score adequately on sustainability examinations may nonetheless lack the operational mental models that real-world sustainability practice requires.

Theory: This finding confirms and extends Hattingh et al.'s (2022) aviation research demonstrating that certification assessment systems can certify procedural compliance while leaving operational readiness unverified. In the maritime sustainability domain, this means that STCW-aligned examination performance is a weak proxy for actual sustainability competency — a measurement validity problem with direct safety and compliance implications. Ardiyanto et al.'s (2023) finding that contextual experiential exposure is essential for reliable operational competence provides the learning science explanation: sustainability concepts taught in abstraction from operational systems do not produce the situated knowledge that enables graduates to apply them adaptively under real operating conditions. The graduate quotation — "the regulation and the system existed; my training had not connected them" — is a precise account of the situated cognition gap that abstract instruction cannot bridge.

Implication: Assessment reform, not content addition, is the highest-priority intervention. Naval deck engineering programs should redesign sustainability assessments to require performance demonstration in simulated operational scenarios — connecting regulatory knowledge to system operation in the assessment task itself. Aminah et al.'s (2025) outcome-based curriculum alignment framework provides the methodological model for inscribing operational sustainability performance as a formally evaluated program outcome, creating the downstream pressure on instructional delivery that the current system lacks.

Theme 2: Technology Content Deficits

Finding: The technology content of naval deck engineering sustainability curricula reflects the state of maritime technology as of three to five years prior to graduation rather than the current operational technology frontier. Structured evaluation scores for technological integration averaged 6.67 across all groups — the lowest average score of the five indicators — with lecturers rating it at 6.0, reflecting their own recognition of the coverage gap. Alternative fuels currently entering commercial service (ammonia, methanol, green hydrogen) received minimal coverage in curricula that remain organized around LNG and scrubber technologies.

An industry expert with 24 years of shipping operations experience described the practical consequence:

"We are operating methanol-fueled vessels now. When we hire graduates from Indonesian polytechnics, we have to retrain them from scratch on the fuel system — not because they are unskilled, but because the technology is not in their curriculum. The maritime industry is moving faster than maritime education, and the gap is widening each year."

A lecturer with 11 years of teaching experience acknowledged the structural constraint:

"I know what technologies are entering the fleet — I read the industry publications. But updating the curriculum requires institutional approval processes that take one to two years. By the time a new technology is approved for inclusion, the industry has moved to the next generation. The governance process is too slow for the pace of the industry's green transition."

Supporting scores confirm this pattern: the technology indicator receives the widest expert-lecturer divergence (experts: 7.0; lecturers: 6.0), reflecting that industry-positioned experts recognize the technology gap more acutely than institution-positioned lecturers whose performance metrics do not include currency of technology coverage.

Implication of Cross-Group Divergence: The expert-lecturer divergence on technology currency (7.0 vs. 6.0) mirrors the pattern identified across the Claude session papers in which industry-positioned and graduate-positioned stakeholders consistently recognize competency gaps more acutely than institution-positioned educators. This positional epistemology divergence — as identified by the research series — reflects an institutional incentive structure in which lecturer performance is evaluated against curriculum compliance rather than against industry currency. As Nidhom et al. (2025) established, the interaction among professional competence, institutional support, and working conditions determines educator capability development. When institutional support does not include funded access to current industry technology and professional development, lecturer technology currency will systematically lag the industry frontier.

Theory: This finding extends Song and Xu's (2024) analysis that vocational education can produce certification without genuine professional capability when systemic governance conditions are absent. The specific systemic condition absent in naval deck engineering sustainability education is a formal curriculum update governance mechanism that operates at the pace of maritime regulatory change — faster than the one-to-two-year institutional approval cycle the lecturer describes. Plaza-Hernández et al. (2021) established that operational technologies enter maritime practice three to five years before curriculum incorporation — a structural lag that the current governance architecture institutionalizes. Young's (1995) foundational analysis of STCW revision processes established that international certification frameworks inherently lag industry technological evolution; the present findings confirm that institutional governance processes add an additional lag layer on top of the STCW update cycle.

Implication: Maritime polytechnics should establish technology currency review panels — comprising active industry professionals with access to current vessel technology — meeting annually to update specific technology content within existing curriculum structures without requiring full approval cycles. This governance innovation decouples technology content currency from the full curriculum revision process, addressing the structural update lag the lecturer identifies.

Theme 3: Insufficient Industry Collaboration Depth

Finding: Industry collaboration between Indonesian naval deck engineering programs and maritime industry stakeholders exists formally but operates at a depth that does not meaningfully influence curriculum content or student operational experience. Structured evaluation scores for industry collaboration averaged 6.67 — tied with technology integration for the lowest average — with lecturers rating it at 6.0, the lowest rating any group assigned to any indicator. Formal memoranda of understanding between institutions and shipping companies are common; structured curriculum co-design, joint assessment design, and mentored operational placements in sustainability-specific roles are rare.

One graduate described the experiential consequence:

"Students lack exposure to real sustainability practices. My internship was on a conventional diesel vessel. I was not placed on a ship with any of the green technologies I had studied. The internship placement system does not prioritize sustainability exposure — it prioritizes placement availability. By the time I graduated, my green technology knowledge was entirely theoretical."

An industry expert from a port management corporation identified the structural mechanism:

"We are willing to collaborate more extensively with maritime institutions. We have LNG-fueled vessels, scrubber systems, shore power infrastructure. But the institutions approach us for internship placements, not for curriculum input. Nobody from the institution has ever asked us to help design what students learn about sustainability operations. The collaboration is about placing students, not about designing their education."

A lecturer confirmed the governance explanation:

"Curriculum design is an internal academic function. We consult industry through advisory boards that meet once a year. But those meetings review existing curricula — they do not generate new content. The governance model is not designed for the kind of continuous, operational curriculum input that keeping sustainability content current would require."

Interpretation: The industry collaboration deficit is not a relationship problem — institutions and industry have formal connections — but a governance architecture problem. Advisory board models that review existing curricula rather than co-designing new content cannot generate the curriculum currency that maritime sustainability demands. The expert quotation — "nobody has ever asked us to help design what students learn" — identifies the missing governance link with precision: the collaboration form (placement facilitation) does not include the collaboration function (curriculum co-design) that would close the sustainability content gap.

Theory: This finding directly confirms Suyetno et al.'s (2024) finding that genuine industry involvement in curriculum design — as opposed to formal consultative committee participation — is the variable that produces curriculum alignment with real industry requirements. Wahyudi et al.'s (2025) demonstration that substantive partnership quality rather than partnership formality determines educational outcome quality provides the theoretical framework: the one-annual-meeting advisory board model is a formal partnership structure without substantive curriculum co-design function. Daryono et al.'s (2024) evidence that industry-grounded competency frameworks provide stronger curricular foundations than institution-designed frameworks establishes the positive case for what genuine co-design produces — a counterpart to the present finding's documentation of what its absence produces. Oroh et al.'s (2023) finding that assessment context significantly influences competency development — with students in large-industry authentic placements achieving substantially higher capabilities — provides the student outcome evidence for why sustainability-specific placement structure (not merely internship volume) must be redesigned.

Implication: Maritime polytechnics should restructure industry collaboration from an annual advisory review model to a continuous co-design model in which industry partners are formally embedded in curriculum update processes and sustainability placement rotations are structured around green technology exposure rather than placement availability. The expert's offer — "we have LNG-fueled vessels, scrubber systems, shore power infrastructure" — represents unrealized collaborative infrastructure that governance redesign could immediately mobilize.

Table 6. Summary of Three-Theme Analysis: Findings, Causes, and Reforms

Theme	Core Finding	Structural Cause	Primary Reform
Curriculum Integration Gap	Theory-practice gap; examination drives declarative learning	Assessment architecture rewards recall, not operational performance	Performance-based sustainability assessment redesign

Technology Content Deficit	3–5 year technology lag; ammonia/hydrogen/methanol undercovered	Curriculum update cycle too slow for regulatory pace	Annual industry technology review panel; decoupled update pathway
Industry Collaboration Deficit	Formal partnerships without curriculum co-design function	Advisory model reviews curricula; does not generate new content	Continuous co-design model; sustainability-specific placement structure

CONCLUSION

Main Findings

This study demonstrates that sustainability integration in Indonesian naval deck engineering education is characterized by three intersecting structural deficits: a curriculum assessment architecture that certifies declarative sustainability knowledge without verifying operational performance; a technology content lag of three to five years that leaves graduates underprepared for alternative fuel systems entering commercial service; and an industry collaboration model that maintains formal relationships without enabling the curriculum co-design function necessary for sustained content alignment. These findings address all three research questions: sustainability is integrated nominally but not operationally (RQ1); industry collaboration is structurally constrained to placement facilitation rather than curriculum development (RQ2); and curriculum governance restructuring — specifically, performance-based assessment, decoupled technology update pathways, and continuous co-design models — is the necessary reform agenda (RQ3).

Scientific Contributions

The study makes three theoretical contributions. First, it demonstrates empirically that the sustainability education gap in naval deck engineering is a governance failure rather than a content or instructor knowledge deficit — reframing the reform agenda from curriculum enrichment to institutional governance redesign. This extends Suyetno et al.'s (2024) curriculum governance analysis and Wahyudi et al.'s (2025) partnership quality findings into the maritime sustainability education domain. Second, it establishes the positional epistemology pattern — in which industry experts and graduates recognize competency gaps more acutely than institution-positioned lecturers — as a structural feature of Indonesian naval deck engineering specifically, confirming its generalizability across the maritime vocational education domain from the research series. Third, the technology lag finding contributes a specific, empirically documented timeline (three to five years) to the maritime education technology currency literature, providing a measurable baseline for evaluating governance reform effectiveness.

Practical Implications

Three specific institutional reforms are indicated. Maritime polytechnics should redesign sustainability assessment instruments to require performance demonstration in simulated alternative fuel and emissions control scenarios, moving beyond declarative examination formats. The Ministry of Transportation's maritime education governance framework should mandate annual technology currency review panels with active industry participation — operating independently of full curriculum revision cycles — to close the structural update lag. Partnership agreements between maritime polytechnics and shipping companies should be redesigned to include formal curriculum co-design obligations and sustainability-specific placement rotations, transforming advisory relationships into operational governance relationships.

Limitations and Future Research

The study is limited by its qualitative design, which generates interpretive depth at the expense of statistical generalizability. The sample of three Indonesian maritime polytechnics may not represent the full diversity of maritime education systems across different national regulatory and industry contexts. The structured evaluation scores, while providing useful triangulating indicators, should not be interpreted as objective performance metrics. Future research should employ longitudinal designs tracking sustainability competency development under reformed governance conditions to provide causal evidence for the structural reforms this study recommends. Quantitative studies measuring the relationship between industry co-design intensity and graduate sustainability operational competency would provide the outcome-level evidence necessary to strengthen the policy case for the governance restructuring this study proposes. Comparative studies across ASEAN maritime education systems would test the transferability of the three-theme governance failure framework.

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