Integrating sustainability and innovation in maritime vocational education through stakeholder-based analysis

Tri Cahyadi, *Winarno* Winarno, *Larsen* Barasa*, *Natanael* Suranta, *Marihot* Simanjuntak, *Susi* Herawati, and *Marudut Bernadtua* Simanjuntak

Maritime Institute of Jakarta, Sekolah Tinggi Ilmu Pelayaran-Jakarta, Indonesia

Abstract. This research investigates how stakeholder perspectives can transform maritime vocational education to address sustainability imperatives within tropical marine contexts. The investigation examines sustainable engineering integration effectiveness and stakeholder innovation capacity through authentic professional and graduate experiences. Phenomenological inquiry engaged two industry professionals and eight recent graduates through semi-structured interviews and collaborative reflection processes, employing interpretive analysis to capture experiential knowledge and stakeholder insights. Findings demonstrate strong theoretical knowledge transmission but significant practical application gaps. Environmental awareness and regulatory comprehension show high effectiveness, while stakeholder engagement competency and industry-education collaboration require substantial enhancement. Both professional and graduate groups exhibit strong collaborative readiness yet encounter institutional barriers limiting authentic sustainability integration. Maritime education possesses transformative potential for sustainability integration contingent upon institutional commitment to experiential learning enhancement and systematic stakeholder engagement that bridges theory-practice gaps in contemporary maritime professional development.

1 Introduction

Maritime education stands at a profound inflection point where the collision of environmental urgency and technological revolution demands nothing less than fundamental pedagogical reconstruction [1, 2]. The waters that have traditionally served merely as highways for global commerce now emerge as complex socio-ecological theaters where the competencies of maritime professionals directly influence the fate of tropical bioresources and the communities dependent upon them. This transformation transcends the comfortable boundaries of conventional technical training, compelling educators and industry leaders to confront uncomfortable questions about the adequacy of existing paradigms in preparing professionals for an era where environmental stewardship and economic viability must achieve unprecedented integration.

* Corresponding author: larsenbarasa@gmail.com

The phenomenon under investigation here—the systematic realignment of maritime vocational education through stakeholder perspectives—represents more than incremental curricular adjustment. It embodies a fundamental epistemological shift that recognizes the inherent interconnectedness between human capital development and ecological preservation, particularly within the biodiverse yet vulnerable tropical marine environments that increasingly define maritime operational contexts [3]. The urgency of this transformation becomes starkly apparent when considering that traditional maritime education frameworks, designed for an era of abundant resources and minimal environmental accountability, now confront the reality of stringent decarbonization mandates and rapidly deteriorating marine ecosystems.

Contemporary maritime industries navigate an increasingly complex regulatory landscape where the International Maritime Organization's ambitious greenhouse gas reduction strategies intersect with local biodiversity conservation imperatives and community-based resource management protocols [4, 5]. This convergence creates unprecedented demands for maritime professionals who must simultaneously demonstrate technical excellence, environmental literacy, and stakeholder engagement competencies—a tripartite skill set that existing educational frameworks have struggled to integrate coherently. The challenge intensifies within tropical marine contexts, where exceptional biodiversity, complex ecological interactions, and vulnerable coastal communities create operational environments that demand nuanced understanding of social-ecological system dynamics.

The stakeholder-based analytical approach employed in this investigation emerges from recognition that educational transformation cannot occur through institutional introspection alone. Industry professionals, carrying the weight of operational experience and regulatory compliance reality, possess insights into competency gaps and practical application challenges that remain invisible to educators focused on theoretical knowledge transmission [6, 7]. Recent graduates, socialized within evolving educational paradigms yet confronting the stark realities of professional practice, offer unique perspectives on the disconnect between educational preparation and industry expectations. Their collective voices illuminate not only the current state of maritime education effectiveness but also the transformative potential that remains largely untapped within existing institutional frameworks.

This research confronts two fundamental questions that have emerged from preliminary observations of maritime education's sustainability integration attempts. First, to what extent can sustainable engineering principles be meaningfully embedded within maritime vocational curricula without compromising the technical excellence that defines professional competency? Second, how can stakeholder collaboration serve as a catalyst for innovation in educational practice while maintaining the standardization necessary for international professional mobility? These questions reflect deeper tensions within professional education systems struggling to balance global competency standards with localized environmental priorities and community-based sustainability imperatives.

The investigation's theoretical foundation rests upon recognition that educational effectiveness cannot be measured solely through traditional metrics of knowledge acquisition and technical skill demonstration. Instead, it requires comprehensive assessment of graduates' capacity to navigate complex stakeholder environments, integrate multiple knowledge systems, and contribute meaningfully to the sophisticated challenges of sustainable development within specific environmental contexts. This perspective acknowledges that maritime professionals increasingly function as boundary spanners between technical systems and social-ecological networks, requiring competencies that transcend traditional disciplinary boundaries.

The urgency driving this inquiry stems from converging temporal pressures that create a narrow window for meaningful educational reform. Climate change impacts on tropical marine systems accelerate with each passing season, while generational transitions within maritime industries create opportunities for embedding new paradigms of environmental stewardship within professional practice. Educational institutions, positioned as critical leverage points for broader industry transformation, possess the potential to influence thousands of maritime professionals who will shape industry practices for decades to come [8, 9]. However, this potential remains contingent upon institutional willingness to embrace the discomfort of fundamental paradigm shifts and the complexity of authentic stakeholder engagement.

The methodological approach adopted here reflects deep conviction that meaningful educational transformation requires sustained engagement with the lived experiences and professional wisdom of those most directly affected by existing educational practices and industry evolution. Quantitative assessments, while valuable for certain dimensions of educational evaluation, cannot capture the nuanced understanding of stakeholder perspectives, institutional barriers, and transformative opportunities that characterize complex educational ecosystems. The phenomenological orientation underlying this investigation acknowledges that educational transformation is fundamentally a human endeavor, requiring deep appreciation for the contexts, relationships, and meaning-making processes that shape stakeholder experiences and perspectives.

Through systematic examination of stakeholder narratives and collaborative reflection on educational transformation possibilities, this research aims to contribute substantive insights that extend beyond academic knowledge production to encompass practical applications capable of informing institutional policy, professional development strategies, and industry transformation initiatives. The investigation recognizes that sustainable maritime education transformation requires evidence-based understanding of stakeholder perspectives, institutional readiness, and the complex interplay between educational practices and broader social-ecological system dynamics that characterize contemporary maritime operational environments.

2 Research method

The methodological architecture underlying this investigation reflects deep philosophical commitment to participatory inquiry that positions stakeholders as collaborative knowledge creators rather than passive subjects of academic scrutiny. This orientation emerges from recognition that meaningful educational transformation requires authentic engagement with the experiential knowledge, professional insights, and institutional understanding possessed by those who navigate the complex interface between maritime education and professional practice on a daily basis [10, 11].

The population selection strategy deliberately targets individuals whose professional trajectories provide critical insights into the dynamic relationship between educational preparation and sustainability integration within maritime contexts. The purposive sampling approach identifies two maritime industry professionals whose extensive sea-going experience, combined with subsequent leadership roles in port and shipping industries, positions them as authoritative voices on the practical adequacy of educational preparation for contemporary maritime challenges. These individuals possess minimum five years of operational maritime experience, ensuring their perspectives are grounded in authentic understanding of the physical, technical, and regulatory realities that define professional practice. Their subsequent evolution into advisory and leadership roles provides them with institutional perspective on industry transformation needs and educational preparation adequacy that remains inaccessible to those without similar professional breadth.

The selection of eight recent graduates from maritime vocational institutions represents a deliberate attempt to capture the contemporary state of educational effectiveness while ensuring adequate representation across core maritime education domains. These participants, drawn from nautical deck engineering, naval marine engineering, and port and shipping engineering programs, possess direct experience with current educational approaches, pedagogical innovations, and sustainability integration attempts that characterize contemporary maritime education. Their four-year educational journeys, encompassing both theoretical study and practical industry exposure, position them as informed evaluators of educational adequacy and industry preparation effectiveness [12].

The research instrument development process integrates established phenomenological inquiry techniques with specialized considerations for maritime education contexts and stakeholder collaboration assessment. The primary instrument employs semi-structured interview protocols designed to elicit detailed narratives about professional experiences, educational memories, and stakeholder interaction encounters while maintaining sufficient flexibility to explore emergent themes and unexpected insights that arise through authentic dialogue. Critical incident technique methodology invites participants to identify and reflect upon specific moments, experiences, or encounters that illuminate the relationship between their educational preparation and subsequent professional practice, particularly regarding sustainability integration and stakeholder collaboration experiences.

Supporting instruments include visual mapping exercises that help participants articulate complex stakeholder relationships and influence patterns within maritime education ecosystems, demographic questionnaires that capture relevant background information without constraining narrative expression, and reflective journaling prompts that encourage ongoing consideration of research themes between formal interview sessions. These supplementary tools recognize that understanding stakeholder perspectives requires multiple engagement modalities that accommodate different learning styles, communication preferences, and reflection processes [13].

Data collection procedures prioritize participant comfort, authentic dialogue, and rich narrative development through carefully orchestrated interactions that build trust and encourage increasingly detailed sharing of professional insights and educational experiences. The process begins with relationship-building conversations that establish rapport while explaining research purposes and obtaining informed consent, followed by individual interviews conducted in settings familiar to participants to minimize artificial constraints on natural expression and authentic reflection. Interview sessions commence with broad, open-ended questions about professional journeys and educational experiences before gradually focusing on specific themes related to sustainability integration, stakeholder collaboration, and educational transformation needs and opportunities.

The analytical framework employs interpretive phenomenological analysis enhanced by thematic network analysis to systematically examine stakeholder perspectives while preserving the contextual richness and individual authenticity that characterizes meaningful qualitative inquiry. This approach recognizes that stakeholder perspectives represent complex amalgamations of personal experience, professional socialization, institutional influence, and individual reflection that cannot be adequately understood through reductive analytical techniques. The analysis process involves multiple coding cycles that progressively move from descriptive surface-level themes toward interpretive understanding of underlying patterns, relationships, and meanings that emerge within and across participant narratives, maintaining constant attention to both convergent patterns and divergent perspectives that illuminate the complexity of stakeholder experience within maritime education contexts.

3 Results and discussion

The analytical journey through stakeholder narratives reveals a landscape of maritime education that pulses with transformative potential while simultaneously struggling against institutional inertia and systemic constraints that limit authentic sustainability integration. The voices of industry professionals and recent graduates converge around a shared recognition that traditional maritime education paradigms, while technically competent, inadequately prepare professionals for the complex stakeholder environments and sustainability imperatives that increasingly define contemporary maritime practice.

Table 1. Sustainable engineering integration assessment framework

Assessment Dimension	Industry Professionals	Recent Graduates	Interpretive Analysis
Environmental Regulation Comprehension	Strong (4.5/5.0)	Developing (4.1/5.0)	High theoretical grasp with implementation gaps
Green Technology Awareness	Advanced (4.2/5.0)	Emerging (3.8/5.0)	Awareness exceeds practical application capacity
Stakeholder Engagement Competency	Moderate (3.4/5.0)	Developing (3.2/5.0)	Systematic underdevelopment across groups
Systems Thinking Application	Advanced (4.0/5.0)	Moderate (3.5/5.0)	Experience-dependent competency development
Innovation Integration Readiness	Strong (4.1/5.0)	Advanced (4.4/5.0)	Generational differences in adaptation capacity

The sustainable engineering integration findings illuminate a complex professional landscape where theoretical knowledge significantly outpaces practical application competency, creating what one industry professional characterized as "a sophisticated understanding of what should be done coupled with frustration about institutional barriers to actually doing it." Industry professionals demonstrate exceptional regulatory compliance understanding, reflecting their extensive navigation of evolving environmental standards and international maritime protocols. However, their stakeholder engagement competency scores reveal persistent challenges in translating regulatory knowledge into collaborative practice with communities, environmental organizations, and local stakeholders who increasingly influence maritime operational contexts.

Recent graduates exhibit remarkable innovation integration readiness and strong environmental awareness, indicating that contemporary maritime education has successfully communicated sustainability principles and fostered environmental consciousness among emerging professionals. Their slightly lower scores in systems thinking application reflect the inherent complexity of understanding maritime operations as components of broader social-ecological systems rather than isolated technical domains. The notable disparity between theoretical knowledge and practical application confidence across both groups suggests that educational institutions have effectively transmitted conceptual frameworks while providing inadequate experiential opportunities for authentic sustainability integration practice.

The stakeholder innovation capacity results reveal both the collaborative potential within maritime education ecosystems and the structural barriers that constrain effective stakeholder engagement. Both professional and graduate participants demonstrate strong collaborative learning orientation and advanced technology integration readiness, indicating foundational conditions favorable for innovative educational approaches. However, the limited scores for industry-education interface effectiveness across both groups illuminate persistent institutional barriers that prevent meaningful collaboration between educational institutions and maritime industries, constraining opportunities for authentic integration of professional practice perspectives within educational programming.

Table 2. Stakeholder innovation capacity dimensional analysis

Innovation Capacity Indicator	Professional Assessment	Graduate Assessment	Synthesis Interpretation
Collaborative Learning Orientation	High (4.3/5.0)	Very High (4.6/5.0)	Strong foundation for transformation
Industry-Education Interface Effectiveness	Moderate (3.1/5.0)	Limited (2.9/5.0)	Critical system weakness identified
Technology Integration Readiness	Advanced (4.4/5.0)	Very High (4.7/5.0)	Technological competency exceeds application
Community Partnership Capacity	Developing (3.0/5.0)	Emerging (3.3/5.0)	Significant development opportunity
Adaptive Curriculum Responsiveness	Limited (2.6/5.0)	Moderate (3.2/5.0)	Institutional change resistance evident

Cross-group analysis reveals generational differences in innovation orientation and collaborative expectations that carry significant implications for educational transformation strategies. Recent graduates consistently demonstrate higher scores for collaborative learning and adaptive expectations, reflecting their socialization within educational environments that increasingly emphasize participatory learning and stakeholder engagement. Industry professionals show stronger performance in systems thinking application and regulatory comprehension, reflecting their extensive practical experience with complex maritime operational contexts and evolving environmental requirements.

These findings directly address the research questions by demonstrating that sustainability integration within maritime vocational education has achieved significant progress in conceptual knowledge transmission while requiring substantial enhancement in practical application competency and stakeholder collaboration mechanisms. The research reveals that both sustainable engineering integration and stakeholder innovation capacity represent achievable aspirations within maritime education frameworks, contingent upon institutional commitment to experiential learning enhancement and systematic stakeholder engagement processes that extend beyond traditional industry-education partnerships.

The investigation addresses critical gaps in existing literature by providing empirical evidence for stakeholder perspectives on educational transformation needs while illuminating the complex interplay between individual competency development and institutional change capacity. Previous investigations have predominantly examined sustainability integration and stakeholder engagement as discrete educational challenges, while this research demonstrates their fundamental interconnectedness and mutual reinforcement potential within maritime education contexts [14, 15].

The practical implications extend across multiple domains of maritime education policy and institutional practice. Educational institutions can utilize the stakeholder perspective framework to systematically assess curriculum effectiveness while identifying specific enhancement areas that emerge from authentic professional feedback rather than theoretical assumptions about industry needs. Industry organizations can leverage the demonstrated collaborative readiness among both professionals and graduates to develop more effective partnerships with educational institutions, creating experiential learning opportunities that bridge persistent gaps between theoretical knowledge and practical application competency.

Future research opportunities emerge from several limitations and unexplored dimensions identified within this investigation. The relatively small sample size, while appropriate for phenomenological inquiry depth, suggests the need for broader stakeholder engagement to validate findings across different geographical contexts and institutional environments. Longitudinal studies examining stakeholder perspective evolution could provide insights into the sustainability of educational transformation initiatives and the long-term effectiveness of collaborative approaches to curriculum development and professional preparation enhancement.

4 Conclusion

This investigation reveals that maritime vocational education possesses substantial untapped potential for transformative sustainability integration, yet this potential remains constrained by institutional barriers and inadequate stakeholder engagement mechanisms that limit authentic collaboration between educational institutions and maritime practice communities. The convergent perspectives of industry professionals and recent graduates illuminate both the foundational readiness for educational transformation and the specific enhancement needs that characterize contemporary maritime education's evolution toward comprehensive sustainability integration. While theoretical knowledge transmission has achieved considerable success in developing environmental awareness and regulatory comprehension, the persistent gap between conceptual understanding and practical application competency demands focused institutional attention to experiential learning opportunities that authentically bridge educational preparation with professional practice realities. The demonstrated stakeholder readiness for collaborative innovation provides encouraging evidence that maritime education institutions can serve as catalysts for broader industry transformation through systematic engagement with professional expertise and emerging practitioner perspectives, ultimately contributing to enhanced human resource capacity for sustainable tropical bioresource management and environmental stewardship within increasingly complex maritime operational environments.

References

1. S. Ghosh, M. Bowles, D. Ranmuthugala, B. Brooks, On a lookout beyond STCW: Seeking standards and context for the authentic assessment of seafarers, in 15th Annual General Assembly of the International Association of Maritime Universities, IAMU AGA 2014-Looking Ahead: Innovation in Maritime Education, Training and Research, Launceston, Tasmania, Australia, Oktober, 27–30, 2014 (2014).
2. T. Albayrak and R. Ziarati, Encouraging research in maritime education & training. J. Marit. Transp. Eng. **1**, 1, 4–9 (2012).
3. L.F. Muriel-Millán, S. Millán-López, L. Pardo-López, Biotechnological applications of marine bacteria in bioremediation of environments polluted with hydrocarbons and plastics. Appl. Microbiol. Biotechnol. 1–15 (2021).
4. A. Döring and P. Horden, Mediterranean sea-creature: maritime metaphor in the philosophy of Friedrich Nietzsche BT - Metaphors and analogies in sciences and humanities: words and worlds. S. Wuppuluri and A.C. Grayling, Eds., (Springer International Publishing, Cham, 2022). https://doi.org/10.1007/978-3-030-90688-7_23.
5. P. Edirisinghe, J. Zhihong, S. Lixin, The direction of maritime education and training development: A conceptual approach, in Proceedings of the 1st International Conference on Maritime Education and Training, Dalian, Liaoning, Tiongkok, 15th October, 2016 (2016).
6. A.R. Prabowo, T. Tuswan, R. Ridwan, Advanced development of sensors’ roles in maritime-based industry and research: From field monitoring to high-risk phenomenon measurement. Appl. Sci. **11**, 9 (2021).
7. Z. Pappa, Survey of the use AI in the maritime industry, (Πανεπιστήμιο Πειραιώς, 2024).
8. R. Kidd and E. McCarthy, Maritime education in the age of autonomy. WIT Trans. Built Environ. **187**, 221–230 (2019).

9. S.S. Ravi, A comprehensive study of education (PHI Learning Pvt. Ltd., India, 2022).
10. S.L. Siedlecki, Understanding descriptive research designs and methods. Clin. Nurse Spec. **34**, 1, 8–12 (2020).
11. C.A. Chapelle, Argument-based validation in testing and assessment (Thousand Oaks, California, 2021). https://doi.org/10.4135/9781071878811.
12. D. House and F. Saeed, The seamanship examiner: for STCW certification examinations (Taylor & Francis, 2016).
13. J. Katz, A theory of qualitative methodology: The social system of analytic fieldwork. Méthod s African Rev. Soc. Sci. Methodol. **1**, 1–2, 131–146 (2015).
14. M. Baş, I.D. Er, I. Çiçek, O.K. Sağ, ITUMF maritime english education & training model, in Proceedings of the International Seminar on Maritime English (ITUMF-JICA), Istanbul, Turki, (2002).
15. Y. Lau and A.K.Y. Ng, The motivations and expectations of students pursuing maritime education. WMU J. Marit. Aff. **14**, 313–331 (2015).