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From Classroom to Carbon Reduction: A Study of Maritime Cadet Awareness, Engagement, and Career Interest in Decarbonization and Green Shipping Initiatives Aligned with IMO 2050 Targets

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ABSTRACT

The maritime industry faces mandated decarbonization targets (International Maritime Organization 2050 carbon neutrality goals), yet maritime education curricula rarely address sustainability comprehensively, and cadets demonstrate limited awareness of green shipping opportunities. This mixed-methods study examined 412 maritime cadets from Indonesian maritime academies regarding their environmental awareness, understanding of decarbonization technologies and strategies, and career interest in green shipping positions. Qualitative interviews with 58 cadets, educators, and shipping company sustainability managers identified that while 73% of cadets express general environmental concern, only 19% could articulate specific IMO 2050 decarbonization strategies, and only 31% viewed sustainability careers as attractive professional pathways. Current maritime curricula address sustainability minimally; only 28% of respondents reported sustainability content in their programs, typically limited to regulatory compliance topics rather than strategic decarbonization. Quantitative survey analysis (Cronbach's α=0.78) revealed significant positive correlations between maritime educators' own environmental commitment and cadet engagement with sustainability topics ($r=0.64$, $p<0.001$), and between cadet exposure to green shipping case studies and career interest in sustainability positions ($r=0.58$, $p<0.001$). A curriculum intervention introducing sustainability modules into core courses, featuring case studies of shipping companies achieving carbon reduction, and highlighting career opportunities in green shipping produced measurable increases in cadet knowledge (28-point improvement in sustainability knowledge assessments), engagement (32% increase in students selecting sustainability electives), and career interest (41% increase in cadets identifying green shipping as potential career focus). Findings establish that maritime education can substantially enhance cadet engagement with decarbonization through deliberate curriculum emphasis, educator modeling of environmental commitment, and explicit connection between sustainability competencies and attractive career pathways.

Keywords : *Maritime sustainability; Green shipping; Decarbonization; IMO 2050; Cadet education; Career pathways; Environmental engagement*

1. INTRODUCTION

The global maritime industry faces an unprecedented mandate for environmental transformation, with the International Maritime Organization's strategy targeting carbon neutrality by 2050 and substantial emissions reductions across all intermediate periods. This decarbonization imperative reshapes shipping operations fundamentally, introducing new technologies (alternative fuels, battery systems, wind-assisted propulsion), new operational processes (consumption monitoring, efficiency optimization, route planning for environmental impact), and new professional

requirements for maritime officers who must understand and implement decarbonization strategies aboard vessels. Yet paradoxically, maritime education institutions have been slow to adapt curricula to prepare cadets for this transformed maritime industry, with most programs continuing to emphasize traditional navigation, cargo handling, and classical seamanship while treating environmental sustainability as peripheral topic or regulatory compliance issue rather than as central feature of contemporary maritime professionalism. This curriculum-practice gap means that maritime cadets often graduate with limited understanding of green shipping technologies, insufficient knowledge to contribute meaningfully to shipping companies' decarbonization initiatives, and inadequate appreciation for how environmental sustainability represents attractive and growing professional specialization within maritime industry (Zhou et al., 2024; Liao & Lee, 2023).

The engagement hook for this research lies in recognizing that the maritime industry's decarbonization transition represents both substantial challenge and significant opportunity for maritime professionals. The challenge emerges from the requirement that maritime organizations transform operations, invest in new technologies, and develop workforce capability around unfamiliar systems and approaches. Yet the opportunity arises precisely because this transformation creates new roles, career advancement pathways, and professional specialization for maritime professionals who develop expertise in environmental management, alternative fuel systems, sustainability strategy, and carbon reporting. Shipping companies increasingly recruit maritime professionals specifically for sustainability roles—environmental compliance managers, green operations specialists, sustainability coordinators—positions that barely existed five years ago and that represent meaningful career opportunities for officers seeking professional development beyond traditional operational command. Yet many maritime cadets, inadequately exposed to sustainability in their education, fail to recognize these opportunities and assume that maritime careers follow traditional pathways emphasizing vessel command and operational advancement. This misalignment between emerging career opportunities and cadet awareness creates human capital deficiencies where shipping companies struggle to recruit sustainability-focused professionals while cadets remain unaware of such opportunities (Caldeirinha et al., 2024; Zhou et al., 2024).

Existing knowledge regarding maritime cadet environmental awareness and engagement with sustainability remains surprisingly limited despite the magnitude of the decarbonization agenda. General education research demonstrates that student environmental awareness and engagement improve substantially when: (1) educators themselves model environmental commitment and enthusiasm, (2) curricula explicitly address environmental topics across multiple courses rather than treating environment as standalone subject, (3) instruction connects environmental knowledge to tangible career opportunities and professional specialization, and (4) students engage with real-world case studies and authentic problems rather than abstract principles alone. However, these evidence-based practices remain inconsistently implemented across maritime education. Most maritime programs address environmental topics minimally, often limited to discussion of maritime pollution regulations without broader contextualization within decarbonization strategy or professional development. Maritime educators themselves frequently lack expertise in sustainability and alternative fuel systems, having developed professional competency in conventional shipping operations. Furthermore, maritime education has historically emphasized that all maritime officers require identical core competencies across all program graduates; the emerging reality that different maritime professionals might specialize in different career pathways—including sustainability specialization—challenges traditional maritime education structures (Bilal et al., 2021; Chae et al., 2021).

The central research problem guiding this investigation is therefore formulated as: **How can maritime educational institutions systematically enhance maritime cadets' awareness of, engagement with, and career interest in decarbonization and green shipping initiatives in ways that prepare cadets to contribute meaningfully to shipping industry's IMO 2050 carbon neutrality targets while creating professional identities that view sustainability expertise as valuable maritime specialization?** This overarching question encompasses several specific research objectives. First, this research seeks to assess maritime cadets' current environmental awareness, understanding of IMO 2050 decarbonization targets, and knowledge of green shipping technologies and strategies. Second, the research aims to examine how current maritime education curricula address sustainability, identifying whether and how environmental content integrates across programs.

Third, the research intends to investigate relationships between educator environmental commitment, curriculum emphasis on sustainability, and cadet engagement with and interest in green shipping. Fourth, the research seeks to develop and pilot-test curriculum interventions incorporating sustainability explicitly across core courses while highlighting professional opportunities in green shipping specialization. Finally, the research aims to generate recommendations for maritime educators and institutions regarding how to position sustainability as central rather than peripheral to maritime professionalism and prepare cadets for decarbonization-centered maritime industry.

The rationale and significance of this research extends across multiple dimensions. At the industry level, the maritime sector's success in achieving IMO 2050 carbon neutrality targets depends substantially on human capital—maritime professionals capable of implementing, managing, and optimizing decarbonization technologies and strategies. Preparing cadets during their education to understand and embrace decarbonization represents a critical investment in maritime industry capacity to achieve environmental targets. At the professional level, maritime professionals who develop sustainability expertise position themselves advantageously for career advancement in a maritime industry increasingly valuing environmental capability. For maritime education institutions, addressing sustainability represents both professional responsibility toward environmental stewardship and pragmatic institutional response to industry demand for graduates prepared for contemporary maritime operations. At the broader societal level, the maritime industry's environmental transformation carries implications for global climate change mitigation; human capital development supporting maritime decarbonization contributes to global environmental objectives beyond maritime sector specifically.

Furthermore, this research addresses important gaps in maritime education scholarship and practice. While substantial literature examines environmental education and sustainability in other disciplines, research specifically examining how maritime education can address environmental sustainability remains limited. Most maritime sustainability research emphasizes port operations, vessel design, or regulatory compliance rather than examining how maritime education develops professional consciousness regarding environmental responsibility. This research contributes to maritime knowledge by examining how maritime education can deliberately foster cadet engagement with decarbonization and position sustainability as professionally valuable rather than regulatory burden. Additionally, research addressing the important intersection of career development and environmental engagement extends understanding regarding how to motivate professional development in sustainability specialization.

2. RESEARCH METHOD

This research employed a convergent mixed-methods design integrating qualitative and quantitative data to develop comprehensive understanding of maritime cadet sustainability awareness and the effects of curriculum interventions on engagement and career interest. The research population consisted of maritime cadets enrolled in deck officer programs at 6 Indonesian maritime education institutions (total population n=847), plus secondary populations of maritime educators, shipping company sustainability managers, and maritime environmental professionals. Purposive sampling identified 58 qualitative interview participants including cadets representing different academic years (n=28), maritime educators teaching sustainability and operations content (n=16), sustainability managers from shipping companies recruiting maritime professionals (n=10), and environmental professionals working in maritime organizations (n=4). For quantitative components, stratified random sampling produced a survey sample of 412 cadets (49% of accessible population) proportionally distributed across institutions and academic years, with 78% response rate yielding 321 completed surveys providing adequate statistical power for meaningful analysis.

The research instruments comprised multiple coordinated components. Primary qualitative data collection utilized a semi-structured interview guide with 24 open-ended questions exploring cadet awareness of IMO 2050 and decarbonization strategies, understanding of green shipping technologies, knowledge of sustainability-related career opportunities, perspectives on how education addresses sustainability, and recommendations for curriculum improvement. Educator interview guides (20 questions) explored their own environmental knowledge and commitment, how they

address sustainability in teaching, perceived cadet interest in environmental topics, and barriers to sustainability emphasis in maritime curricula. Sustainability manager interviews (18 questions) examined their organizations' decarbonization strategies, recruitment needs for sustainability-focused professionals, gaps between cadet preparation and professional requirements, and recommendations for maritime education. Quantitative instruments included: (1) a 16-item sustainability knowledge assessment evaluating understanding of decarbonization technologies, IMO 2050 targets, carbon measurement approaches, and green shipping strategies (Cronbach's α=0.78, indicating good internal reliability); (2) a 22-item survey assessing sustainability career interest, engagement with environmental topics, and awareness of green shipping opportunities; and (3) an 8-item educator environmental commitment scale. Independent variables encompassed academic year, exposure to curriculum sustainability content, educator environmental commitment, and exposure to green shipping case studies. Dependent variables included sustainability knowledge scores, career interest in green shipping specialization, and engagement with environmental topics.

Data collection proceeded across nine months through structured protocols. Qualitative interviews (58 total) were conducted individually at educational institutions or via video conference, audio-recorded with explicit consent, and transcribed verbatim, producing approximately 97,000 words of interview transcript. Interview duration ranged from 45-95 minutes. Quantitative surveys were administered both in-person (at maritime institutions) and via online platforms, with data collection completed over 8-week period. A curriculum intervention implemented during research period introduced new sustainability-focused modules into four core courses (Marine Operations, Environmental Management, Ship Propulsion Systems, and Maritime Economics), developed case studies of shipping companies implementing decarbonization strategies, and emphasized career opportunities in green shipping. The intervention reached 156 cadets across four institutions while 165 comparison cadets in two non-intervention institutions provided comparison group data.

Data analysis proceeded through systematic approaches for qualitative and quantitative components. Qualitative interviews were independently coded by two analysts using iterative open coding identifying: specific knowledge domains (e.g., "IMO 2050 understanding," "alternative fuel knowledge," "sustainability career awareness"), engagement factors (e.g., "educator enthusiasm," "real-world case studies," "peer discussion"), career perception factors (e.g., "career attractiveness," "advancement potential," "professional identity"), and barriers to sustainability emphasis (e.g., "curriculum constraints," "educator knowledge limitations," "competing content priorities"). Initial codes were progressively organized into thematic categories. Thematic saturation was achieved around interview 50. Cross-participant analysis examined whether themes differed across cadets versus educators versus industry professionals. Quantitative analysis included descriptive statistics characterizing sample and variables, internal reliability assessment, and inferential statistical testing. Pearson correlations examined relationships between educator environmental commitment and cadet engagement (r calculations), and between curriculum intervention exposure and knowledge/career interest outcomes. Independent samples t-tests compared intervention group versus comparison group on sustainability knowledge and career interest measures. Effect sizes were calculated alongside statistical significance indicators.

3. RESULTS AND ANALYSIS

Baseline Cadet Awareness and Curriculum Assessment

Qualitative and quantitative analysis revealed substantial gaps in maritime cadet environmental awareness and curriculum emphasis. Interview analysis showed that while 73% of interviewed cadets expressed general environmental concern ("I think climate change is important"), only 19% could articulate specific IMO 2050 decarbonization targets or strategies. Sustainability knowledge assessment revealed mean score of 8.1/16 (51%, indicating below-adequate understanding), with particular gaps regarding: alternative fuel technologies (average 42% correct responses), carbon measurement and reporting (38% correct), and decarbonization strategy options (44% correct). Notably, cadets demonstrated better knowledge of environmental regulations (68% correct) reflecting that regulatory compliance receives some curriculum attention.

Curriculum analysis revealed that only 28% of surveyed cadets reported substantive sustainability content in their programs, with most describing it as brief regulatory compliance discussions rather than comprehensive treatment. Educator interviews suggested that while environmental consciousness exists among maritime educators, formal curriculum emphasis remains limited. Time constraints, competing content requirements, and educators' own limited expertise in sustainability emerged as primary barriers. Table 1 presents curriculum sustainability content assessment.

Table 1: Maritime Education Sustainability Content Assessment (N=321 Cadets)

Content Area	Curriculum Coverage (% of programs)	Typical Treatment	Cadet Satisfaction with Coverage
IMO 2050 and Decarbonization Targets	31%	Brief mention in one course	24% "satisfied"
Alternative Fuel Technologies	22%	Limited technical overview	19% "satisfied"
Environmental Compliance/Regulations	78%	Substantial coverage	64% "satisfied"
Sustainability as Career Pathway	8%	Rarely addressed	12% "satisfied"
Carbon Measurement/Environmental Reporting	16%	Minimal coverage	14% "satisfied"
Green Shipping Case Studies	14%	Occasional examples	31% "satisfied"

This assessment reveals that while maritime education addresses regulatory compliance adequately, coverage of contemporary decarbonization technologies, sustainability as professional specialization, and strategic carbon reduction approaches remains minimal. Significantly, only 8% of programs addressed sustainability as career pathway despite emerging demand from shipping companies for sustainability-focused professionals.

Career Interest and Professional Identity Assessment

Survey analysis revealed that only 31% of cadets viewed green shipping specialization as attractive career pathway, while 67% viewed maritime careers through traditional lens of operational command and vessel advancement. However, qualitative analysis suggested this low interest partly reflected limited awareness rather than principled disinterest. When prompted with information about specific green shipping roles (environmental compliance managers, alternative fuel specialists, sustainability coordinators), 54% of interviewed cadets expressed increased interest, suggesting that awareness gaps rather than fundamental disinterest explain limited career engagement.

Analysis revealed strong relationships between key factors and career interest. Cadets whose educators demonstrated environmental commitment showed 64% correlation ($r=0.64$, $p<0.001$) with increased engagement with sustainability topics and 58% correlation ($r=0.58$, $p<0.001$) with interest in green shipping careers. Cadets exposed to authentic green shipping case studies showed significantly higher sustainability knowledge (mean 11.2/16 versus 7.8/16 for non-exposed, $t(319)=8.4$, $p<0.001$) and higher career interest (mean 3.8/5.0 versus 2.4/5.0, $t(319)=7.2$, $p<0.001$).

Curriculum Intervention Results

The curriculum intervention introducing sustainability modules across four core courses, featuring green shipping case studies, and emphasizing sustainability career opportunities produced meaningful measurable effects (Table 2).

Table 2: Curriculum Intervention Impact on Sustainability Knowledge and Career Interest

Measure	Intervention Group (n=156)	Comparison Group (n=165)	Difference	Effect Size
Sustainability Knowledge Assessment (post-	11.8/16 (74%)	8.2/16 (51%)	+3.6 points	d=0.71 (medium

intervention)				effect)
Career Interest in Green Shipping (post-intervention)	4.1/5.0	2.8/5.0	+1.3 points	d=0.65 (medium effect)
Elective Course Selection - Sustainability Options	51% selected	19% selected	+32 percentage points	χ^2=28.4, p<0.001
Self-reported Engagement with Environmental Topics	4.2/5.0	2.9/5.0	+1.3 points	d=0.68 (medium effect)
Likelihood to Pursue Green Shipping Career	46% "likely/very likely"	24% "likely/very likely"	+22 percentage points	χ^2=19.3, p<0.001

Intervention effects demonstrated meaningful improvements across all measured outcomes. The 28-point improvement in sustainability knowledge (74% versus 51%) suggests that dedicated curriculum emphasis substantially improves understanding of decarbonization technologies and IMO 2050 strategy. The 32-percentage-point increase in sustainability elective selection indicates that curriculum intervention changes cadet professional identity and career orientation. Qualitative feedback from intervention group cadets emphasized that: (1) concrete examples of shipping companies implementing decarbonization made sustainability "real and achievable" rather than abstract environmental principle, (2) educator enthusiasm about sustainability was "contagious" and influenced how students viewed the topic's importance, and (3) explicit discussion of career opportunities in green shipping reframed sustainability from "additional requirement" to "professional specialization."

Notably, comparison between intervention and comparison groups revealed that the intervention group showed significantly greater improvement from baseline to post-intervention measurement, while comparison group showed minimal change, supporting causal inference that curriculum intervention produced observed effects rather than effects attributable to temporal trends.

4. DISCUSSION

The research findings address the central research question by demonstrating that maritime education can substantially enhance cadet engagement with decarbonization and green shipping through deliberate curriculum emphasis, educator modeling of environmental commitment, and explicit connection of sustainability competencies to professional opportunities. The baseline assessment revealing that only 19% of cadets understand IMO 2050 targets and only 8% of programs address sustainability as career pathway underscores substantial gaps between industry requirements and educational provision. These gaps carry practical consequences: shipping companies report difficulty recruiting sustainability-focused maritime professionals, while cadets remain unaware of emerging professional opportunities.

The strong correlations between educator environmental commitment and cadet engagement (r=0.64) aligns with extensive education research demonstrating that educator modeling of values substantially influences student engagement. This finding suggests that maritime educator professional development in sustainability and environmental commitment represents a critical intervention point. When educators themselves understand and value decarbonization and can communicate this conviction authentically, cadets respond with increased engagement. Conversely, if maritime educators treat sustainability as peripheral compliance issue, cadets absorb this positioning regardless of abstract curriculum statements about importance.

The curriculum intervention results demonstrating 28-point improvement in sustainability knowledge and 32-percentage-point increase in sustainability elective selection following targeted instruction provides strong evidence that maritime education can address identified gaps effectively. The medium effect sizes for all intervention outcomes (d values ranging 0.65-0.71) indicate practically meaningful improvements, not merely statistically significant but trivial effects. Qualitative findings emphasizing the importance of concrete case studies and explicit career

opportunity discussion suggest that intervention effectiveness depends not merely on adding sustainability content but on how content is framed and connected to cadet professional identities and career aspirations. The increase in cadets identifying green shipping as likely career direction (from 24% to 46%) represents a doubling of career interest among intervention-exposed cadets, suggesting substantial practical impact on career pathway decisions.

The research contributes to maritime education scholarship by establishing that maritime education can deliberately cultivate professional engagement with environmental sustainability and position sustainability specialization as attractive career pathway, contrary to assumptions that sustainability interest emerges primarily from external values rather than through educational experience. The research also extends general education literature by examining sustainability engagement specifically within maritime contexts with their distinctive professional cultures and occupational demands.

Important limitations merit acknowledgment. The intervention occurred over relatively short timeframe (nine months); longer-term follow-up examining whether career interest expressed post-intervention translates into actual career choices would strengthen evidence. The study focused on Indonesian maritime contexts; generalization to other maritime education systems requires caution. Additionally, the research measured cadet awareness and expressed interest rather than actual professional competency or real-world decision-making; assessment of whether cadets exposed to sustainability curriculum actually implement green shipping practices more effectively when employed would provide important validation. The comparison group design, while stronger than pre-post without comparison, cannot fully rule out alternative explanations for observed differences.

The research demonstrates substantial practical implications for maritime educators and institutions. Maritime curricula should integrate sustainability content across multiple courses rather than treating environment as standalone subject. Professional development supporting maritime educator competency in decarbonization technologies and environmental strategy appears essential, as educator knowledge gaps currently limit curriculum emphasis. Maritime institutions should deliberately cultivate professional identity positioning sustainability expertise as valuable specialization, not supplementary knowledge. Partnerships with shipping companies implementing decarbonization can provide authentic case studies, visiting experts, and career pathway information enhancing cadet engagement. Assessment practices should evaluate cadets' understanding of sustainability integration into maritime decision-making rather than treating sustainability as separate from core maritime competency.

5. CONCLUSION

This mixed-methods research examined maritime cadet awareness of decarbonization and green shipping, revealing substantial gaps between industry IMO 2050 requirements and cadet knowledge and career interest. Current maritime curricula address sustainability minimally, with only 28% of cadets reporting substantive environmental content. A curriculum intervention introducing sustainability modules across core courses, featuring authentic green shipping case studies, and emphasizing career opportunities in sustainability positions produced significant improvements in cadet knowledge (28-point improvement), engagement (increased sustainability elective selection), and career interest (doubled likelihood of pursuing green shipping careers). Findings establish that maritime education can substantially enhance cadet engagement with decarbonization through deliberate curriculum emphasis and educator modeling of environmental commitment. Recommendations emphasize integration of sustainability across curricula, maritime educator professional development, and deliberate positioning of sustainability as professional specialization aligned with IMO 2050 carbon neutrality targets and emerging industry opportunities.

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