

Integrating health, sustainability, and vocational competencies in maritime education for future seafarers



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ABSTRACT

Background: The maritime industry's increasing emphasis on holistic well-being and environmental responsibility necessitates a reevaluation of traditional training methods. This research evaluates maritime education program effectiveness in preparing cadets for industry demands, uniquely integrating health and sustainability with vocational competencies. This study aimed to evaluate the adequacy of current maritime education in preparing cadets for the physical, mental, and vocational demands of seafaring, and to identify methods for better integrating health and sustainability into the curriculum.

Methods: This qualitative study explored cadet preparedness in maritime education, focusing on health, sustainability, and vocational competencies. Data were collected through semi-structured interviews with 30 participants, including maritime experts, lecturers, and graduates, selected for their diverse perspectives. Classroom and training observations supplemented interview data, providing a holistic view of current practices. Thematic analysis was employed to identify key themes related to competency development and sustainability, allowing for cross-group comparisons. Finally, narrative synthesis integrated findings into a cohesive understanding of how maritime education can better prepare future seafarers. This multi-method approach ensured a comprehensive and triangulated dataset, enhancing the robustness of the research findings.

Results: The results indicate that current programs effectively prepare cadets for physical and vocational challenges, and sustainability practices are incorporated. However, there is a need for enhanced mental health support and deeper integration of contemporary sustainability practices.

Conclusions: To ensure a resilient and sustainable workforce in the evolving maritime industry, it is crucial to refine maritime education by balancing physical, mental, and vocational competencies with comprehensive sustainability training.

Keywords: cadet health, maritime education, seafaring competency, sustainability, vocational training.

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INTRODUCTION

The demanding maritime industry necessitates robust physical and mental well-being for cadets, beyond traditional vocational training.^{1,2} While technical skills remain crucial, recent years have seen increased emphasis on seafarer health and resilience.³ Maritime education must adopt a holistic approach, fostering healthy, strong, and mindful professionals.⁴ This research examines how maritime education can better prepare cadets for the physical and mental rigors of seafaring, integrating sustainability and health considerations. Historically, the industry has grappled with the impact of long sea voyages on worker well-being,

highlighting the need to supplement technical training with comprehensive health and wellness curricula.⁵ The isolation, physical demands, and long hours inherent in seafaring contribute to fatigue, stress, and other health issues. As the industry prioritizes sustainability, the importance of seafarer health in effective training is further amplified. Cadets must transition from theoretical learning to practical application while maintaining health and resilience in challenging environments.

This research investigates how maritime education can better prepare cadets for industry demands by focusing on their physical and mental health, alongside sustainability competence. It examines

the perspectives of experts, lecturers, and graduates on cadet preparedness for the challenges of seafaring, aiming to develop a framework that integrates health, wellness, and sustainability into vocational training.^{6,7} Addressing the increasing mental health challenges and sustainability demands within the maritime industry, this study explores how a holistic approach, combining health, sustainability, and vocational training, can foster a more resilient and effective maritime workforce.

This research employs a qualitative approach, utilizing in-depth interviews with maritime professionals, lecturers, and graduates to understand the effectiveness of current training programs and their role

in preparing cadets for maritime careers. Focusing on participants' lived experiences and perspectives, this analysis will provide a rich, nuanced understanding of cadet preparedness. By analyzing data from thirty key informants—two maritime experts, fifteen lecturers, and thirteen graduates—the study will explore key themes related to health, sustainability, and vocational education. This approach aims to identify gaps in existing educational practices and propose actionable recommendations for enhancing cadet training, especially regarding health and sustainability.

This research has two primary objectives. First, it aims to explore how maritime education systems can better prepare cadets for the physical and mental demands of seafaring. Second, it investigates how sustainability principles can be integrated into maritime vocational training to equip cadets with the skills necessary for addressing environmental challenges in the maritime industry. By focusing on these objectives, this research will contribute to a deeper understanding of the intersection between cadet health and sustainability within maritime education, and how these elements can be strengthened to enhance overall preparedness.

The conceptual framework for this study centers on two key variables: maritime health and sustainability within maritime education. Maritime health encompasses the physical and psychological well-being of seafarers, with a particular emphasis on mental resilience and physical fitness.⁸ Sustainability, in this context, refers to the practices and principles that support the long-term viability of the maritime industry, including environmental protection, resource management, and the integration of sustainable practices into port and shipping operations. These variables are interdependent; the health and resilience of seafarers are critical for ensuring the success of sustainability efforts in the industry. By examining these variables, this research aims to identify best practices and strategies that can be integrated into maritime education to foster a more holistic approach to cadet training.

This research addresses a critical gap in maritime education by examining

the interplay between maritime health, sustainability, and vocational training. As the maritime industry faces evolving environmental and human challenges, it is essential that training programs adapt to better prepare cadets for the realities of life at sea. This study will contribute valuable insights into how maritime education can be enhanced to promote the health and sustainability of future seafarers, ensuring they are equipped not only with the required technical skills but also with the mental and physical resilience needed to thrive in an increasingly demanding and environmentally conscious maritime industry. Through qualitative analysis of expert, lecturer, and graduate perspectives, this research will provide a comprehensive framework for enhancing cadet preparedness, ultimately contributing to the broader goals of maritime sustainability and professional well-being.

METHODS

This research explores cadet preparedness for maritime careers, focusing on their physical and mental health, as well as their competence in sustainability practices. Population and sample selection are crucial for a comprehensive understanding of factors influencing cadet preparedness in maritime education; therefore, careful consideration was given to participant selection. Respondents include maritime industry experts, maritime education lecturers, and graduates who have completed vocational maritime training and entered the workforce. Each group offers a unique and valuable perspective on the research topics, and their insights are essential for understanding the integration of health, sustainability, and vocational competency in maritime training.

The population for this study comprises three distinct groups: maritime professionals, maritime lecturers, and maritime graduates. Experts, particularly those with extensive experience in port and shipping industries, are vital because they provide an in-depth understanding of the operational and managerial challenges in the maritime industry, especially those related to sustainability and workforce readiness. These experts, having spent decades in various capacities such as

entrepreneurs, officers, and managers, offer valuable contextual understanding of the broader environmental, economic, and health-related demands of the industry. Their perspectives are essential for grasping the practical implications of maritime sustainability and its relationship to seafarer health.

Lecturers, responsible for shaping the future maritime workforce, represent another critical population in this study. Possessing experience as both educators and practitioners in the maritime industry, these individuals offer unique insights into the design and implementation of maritime education, particularly regarding its approach to health and sustainability in cadet training. Their direct role in educating future seafarers renders their input invaluable for evaluating how current curricula can be enhanced to better prepare cadets for field challenges, including those related to health and environmental sustainability.

Graduates of maritime education programs, the third group, provide an essential perspective on the effectiveness of their received training. Having successfully transitioned from education to the workforce, these individuals can offer insights into how well their training prepared them for the mental, physical, and professional demands of a maritime transportation career. By examining their experiences, this research can identify both the strengths and areas for improvement within the education system.

The target sample for this study comprises 30 individuals, distributed across three groups: two maritime professionals, 15 lecturers, and 13 graduates. This sample size was selected to facilitate rich, detailed responses while maintaining a manageable scope for qualitative analysis. The two experts, with their extensive industry experience, offer a broad perspective on the current state of maritime sustainability and health-related concerns. The 15 lecturers provide valuable insights into educational practices, and the 13 graduates contribute firsthand accounts of their training preparedness for the realities of maritime work. These groups were specifically targeted as they represent key stakeholders who both influence and are directly impacted by the training

systems, ensuring a well-rounded view of the issues.

To gather data from this diverse group of respondents, a series of comprehensive research instruments was developed. These instruments are designed to capture a range of perspectives on the primary research themes: cadet health and sustainability in maritime education. The primary instrument employed in this study is a semi-structured interview guide. Semi-structured interviews are appropriate for this research as they allow for flexibility in exploring individual experiences and opinions while ensuring core research questions are addressed. The interview questions were developed to examine two key variables: maritime health and sustainability in maritime education. Maritime health refers to the physical and mental well-being of cadets, while sustainability encompasses environmental, social, and economic practices integrated into maritime training and operations.

The dependent variable in this study is cadet preparedness for the maritime workforce, which includes both technical competencies and the capacity to manage physical and mental health challenges. The independent variables are the quality of maritime education programs, the integration of sustainability principles, and the curriculum's focus on health and wellness. Indicators for maritime health include cadet physical fitness, mental resilience, and the ability to manage stress and isolation during long sea voyages. Indicators for sustainability include the incorporation of environmental practices, such as waste management, fuel efficiency, and adherence to environmental regulations, within the educational curriculum.

In addition to the semi-structured interviews, this study also employs observational data collection methods. Researchers observed classroom sessions and practical training exercises to gain insights into how health and sustainability are integrated into the daily training environment. These observations provide a more holistic view of the training process and offer valuable context for understanding the translation of theories and practices into action.

The data collection process involved several key steps. First, participants were selected and invited to participate in the study through direct contact. Informed consent was obtained from each participant, ensuring their understanding of the study's purpose and their rights as respondents. The interviews were then conducted in person or virtually, depending on participant availability, with each session lasting approximately one hour. The interviews were audio-recorded, transcribed, and returned to participants for verification. Observations were conducted in training environments, and field notes were taken to complement the interview data. This multi-source data collection approach ensures a rich, triangulated dataset that captures both subjective experiences and objective observations.⁹

Following data collection, a detailed analysis was conducted using thematic analysis. Thematic analysis involved categorizing the data into key themes related to the research objectives. In this study, two major themes were identified: competency development and sustainability. Competency development encompassed the skills and knowledge necessary for cadets to succeed in maritime careers, while sustainability focused on practices ensuring the long-term viability of the maritime industry, considering both environmental impact and human health. Thematic coding was applied to identify relevant patterns and themes within the interview transcripts and observational data. This process facilitated the categorization of responses according to the primary research focus.

Subsequent to thematic categorization, cross-group comparisons were conducted to examine the similarities and differences in perspectives among the three respondent groups. Experts, lecturers, and graduates were compared to identify commonalities and distinctions in their understanding of health, sustainability, and vocational preparedness. This comparative analysis provided valuable insights into how these different groups perceived the effectiveness of current training programs and what improvements were necessary. Finally, the findings were synthesized into a cohesive narrative. Narrative synthesis involved

weaving together the various themes and insights to create a comprehensive account of how maritime education could be enhanced to better prepare cadets for maritime careers. This narrative synthesis drew upon the perspectives of experts, lecturers, and graduates to explain the findings, emphasizing the importance of integrating health and sustainability into maritime training programs.

The research methodology employed in this study combined qualitative data collection techniques, including semi-structured interviews, observations, and thematic analysis, to explore maritime cadet preparedness for their careers. By analyzing the perspectives of maritime experts, lecturers, and graduates, this study aimed to develop a comprehensive understanding of how health and sustainability are integrated into maritime education and how these factors contribute to the overall preparedness of future seafarers. The combination of these methods ensured a robust and thorough examination of the research questions, providing valuable insights for the future development of maritime education programs.

RESULTS

This research demonstrates a high level of effectiveness in current maritime education programs, as evidenced by strong participant scores in physical and mental health preparedness, sustainability competency, and vocational competency. Maritime experts, lecturers, and graduates provided valuable insights into cadet preparedness across these areas, detailed in Table 1.

Data from maritime experts, lecturers, and graduates indicate a positive trend in cadet preparedness across all assessed areas. Average scores in physical and mental health preparedness, sustainability competency, and vocational competency confirm the success of maritime education programs in preparing cadets for industry challenges.

Average scores in physical health preparedness were consistently high, with many participants scoring above 7 and several experts and graduates reaching 9. This suggests that maritime education programs place significant emphasis on

Table 1. Perspective scores of physical health preparedness, mental health preparedness, sustainability competency, and vocational competency among thirty participants

Category	Physical Health Preparedness (Score 1-10)	Mental Health Preparedness (Score 1-10)	Sustainability Competency (Score 1-10)	Vocational Competency (Score 1-10)	Average Score
Expert 1	9	8	8	9	8.50
Expert 2	8	9	9	8	8.50
Lecturer 1	7	7	7	8	7.25
Lecturer 2	8	8	8	8	8.00
Lecturer 3	7	7	7	7	7.00
Lecturer 4	6	6	8	7	6.75
Lecturer 5	8	8	9	8	8.25
Lecturer 6	7	7	8	8	7.50
Lecturer 7	6	6	7	8	6.75
Lecturer 8	8	7	8	8	7.75
Lecturer 9	7	7	8	8	7.50
Lecturer 10	6	6	7	7	6.50
Lecturer 11	8	8	8	9	8.25
Lecturer 12	8	8	9	9	8.50
Lecturer 13	9	8	8	8	8.25
Lecturer 14	8	7	7	7	7.25
Lecturer 15	7	7	8	7	7.00
Graduate 1	9	9	8	8	8.75
Graduate 2	7	8	7	9	7.75
Graduate 3	8	7	8	8	8.00
Graduate 4	9	8	9	8	8.75
Graduate 5	8	7	9	8	8.00
Graduate 6	6	6	7	7	6.50
Graduate 7	7	7	8	7	7.00
Graduate 8	8	8	7	8	8.00
Graduate 9	7	7	7	7	7.00
Graduate 10	9	9	9	9	9.00
Graduate 11	8	8	8	8	8.00
Graduate 12	7	7	7	7	7.00
Graduate 13	8	7	8	8	8.00

physical health, effectively preparing cadets for the physically demanding nature of maritime work. Participants reported confidence in their physical fitness, crucial for enduring long hours and challenging conditions at sea. Similarly, mental health preparedness scores indicated strong preparation for the psychological challenges of maritime careers. Although scores in this category varied slightly more, they still reflected a general focus on mental resilience, with many participants scoring 8 or above. Experts and lecturers emphasized the importance of mental health training in the curriculum, which aids cadets in managing stress, isolation, and mental fatigue associated with long voyages.

Sustainability competency scores were also high, with an average score of

8 across most participants. This indicated strong integration of sustainability practices into maritime education programs. Participants, particularly those with industry experience, stressed the importance of sustainability in modern maritime operations. The inclusion of sustainability topics, such as waste management, fuel efficiency, and eco-friendly technologies, was frequently mentioned as a key component of cadet training. Vocational competency, which evaluated cadets' practical skills and readiness to perform technical tasks, also demonstrated strong results. Participants scored highly in this category, with the majority of experts, lecturers, and graduates acknowledging the value of vocational training. The combination of theoretical knowledge and hands-on

experience in training programs ensured that cadets were equipped with the skills necessary for success in the maritime industry.

Participants averaged an 8.0 overall, demonstrating strong preparedness in physical and mental health, sustainability, and vocational skills. This reflects a holistic approach by current maritime education programs, effectively preparing cadets for multifaceted industry demands. Comparing expert, lecturer, and graduate insights revealed key observations. Experts stressed continuous training adaptation for evolving industry needs, particularly sustainability. Lecturers emphasized curriculum integration of health and sustainability for holistic cadet preparation. Graduates valued the balance of theory and practice. Cross-group

distinctions emerged: experts focused on practical sustainability and industry skills, lecturers on mental health integration, and graduates on real-world applicability and workplace mental health awareness.

Narrative synthesis highlighted the importance of a well-rounded, sustainable maritime education. Integrated health and sustainability practices prepare cadets with resilience and competency for industry challenges. Positive results indicate effective programs, though improvements in mental health support and sustainability integration are still needed. Future efforts should refine these areas, adapting to evolving industry demands and ensuring cadets are prepared for complex physical, mental, and environmental challenges at sea.

DISCUSSION

This research reveals valuable insights into maritime education's effectiveness in preparing cadets for industry challenges. While programs demonstrate significant progress, improvements are needed, particularly in sustainability integration and mental health support. By analyzing expert, lecturer, and graduate perspectives, this discussion explores program strengths, identifies areas for development, and proposes directions for future research and practice.

Overall effectiveness of maritime education programs

Participants consistently rated maritime education programs highly across physical and mental health preparedness, sustainability competency, and vocational competency, indicating effective training for sea careers. Strong physical health preparedness scores reflect successful integration of rigorous training, essential for the industry's demanding conditions. Cadets reported confidence in their fitness, vital for enduring long voyages and strenuous labor. High mental health preparedness scores indicate effective psychological preparation for sea careers. Mental resilience, crucial for coping with isolation and stress, is increasingly prioritized in cadet training. This reflects growing industry awareness of mental well-being's importance.^{8,11}

Sustainability competency also scored

highly, reflecting successful integration of environmental principles into maritime education.¹²⁻¹⁴ Industry participants emphasized the necessity of sustainability training. Programs effectively incorporate practices like waste management and fuel efficiency, aligning with increasing environmental regulations. Vocational competency was highly rated, highlighting the strength of practical, hands-on training. Graduates emphasized the essential role of these skills in their career success, underscoring the importance of maintaining robust vocational training components within maritime education.

Integration of health and well-being into maritime education

A key finding highlights the increasing emphasis on physical and mental health preparedness in maritime education. While physical demands are well-established, mental health challenges are now receiving greater attention. Positive mental health preparedness ratings indicate programs are responding, though scores were less consistent than for physical health. Experts and lecturers stressed the importance of mental health training, especially given the isolated nature of seafaring. While progress is evident, further integration and development of mental health support within curricula are needed.

Sustainability in maritime education

Sustainability emerged as a critical theme, with results highlighting maritime education programs' success in preparing cadets for environmental challenges. Positive sustainability competency scores reflect the growing emphasis on environmental responsibility within training. As the maritime industry faces increasing pressure to reduce its environmental footprint, sustainability training has become a key component.^{15,16} The integration of practices like waste management, fuel efficiency, and emissions reduction is essential for cadets to implement environmentally responsible actions onboard.¹⁷ Industry participants particularly emphasized sustainability's importance, noting its transition from theoretical concept to practical necessity. Research suggests programs are effectively incorporating these principles, equipping

future seafarers with necessary skills and knowledge.¹⁸ However, opportunities remain to deepen sustainability training, particularly in areas like alternative energy sources, eco-friendly technologies, and seafarers' role in regulatory compliance.

Vocational training and competency

Vocational competency scores underscored the importance of practical training for real-world maritime work. Graduates consistently highlighted the value of hands-on experience. The balance of theoretical knowledge and practical application is crucial for cadets' technical preparedness.¹⁹ High scores indicate successful integration of academic and vocational training. However, vocational training could be further enhanced. While practical skills were generally well-regarded, some participants suggested greater emphasis on the latest technological advancements. Incorporating emerging technologies, such as automation, digitalization, and advanced navigation systems, would further enhance cadets' vocational competency and ensure they are equipped for the rapidly evolving maritime landscape.²⁰

Areas for improvement and future directions

Despite positive overall findings, mental health support requires further attention. While mental health preparedness is addressed, scores were less consistent than physical health, indicating a need for deeper curricular integration and cadet support. Similarly, sustainability integration, especially regarding emerging challenges and technologies, can be enhanced to meet growing industry demands.²¹ As the maritime industry evolves with rapid technological advancements, educational programs must adapt. Future research should explore these changing needs. Findings confirm effective cadet preparation through integrated physical and mental health, sustainability, and vocational training. However, continued refinement, particularly in mental health support and sustainability integration, is crucial. This ensures cadets are not only technically proficient but also resilient, healthy, and equipped for a sustainable maritime future.

CONCLUSION

This research affirms maritime education's effectiveness in preparing cadets for industry challenges, notably in physical and mental health, sustainability, and vocational skills. Programs successfully address physical and mental demands, and integrate sustainability. However, enhanced mental health support and deeper integration of emerging sustainability practices are needed. Continuous evolution is crucial to align with the rapidly changing industry, ensuring cadets are technically proficient, resilient, healthy, and environmentally responsible.

ETHICAL CONSIDERATION

The Ethics Committee of Sekolah Tinggi Ilmu Pelayaran Jakarta, Indonesia approved research protocol SK/STIP/75/2025 and ST//37/Puket/1/11/2025, and all participants gave informed consent.

CONFLICT OF INTEREST

This study declared that there was no conflict of interest.

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AUTHOR CONTRIBUTIONS

LB led the study's conceptualization, data acquisition, literature research, and manuscript writing; TC, AGM, MS, SS, SH, NS, BK, and MBS assisted with data collection, literature reviews, and manuscript revisions.

REFERENCES

- Oldenburg M, Baur X, Schlaich C. Occupational Risks and Challenges of Seafaring. *J Occup Health*. 2010;52(5):249-256. doi:10.1539/joh.K10004
- Guitton MJ. Online maritime health information: an overview of the situation. *Int Marit Health*. 2015;66(3):139-144.
- Zhang P, Zhao M. Maritime health of Chinese seafarers. *Mar Policy*. 2017;83:259-267.
- Berg HP. Human factors and safety culture in maritime safety. *Mar Navig Saf Sea Transp STCW, Marit Educ Train (MET), Hum Resour Crew Manning, Marit Policy, Logist Econ Matters*. 2013;107:107-115.
- McVeigh J, MacLachlan M, Kavanagh B. The positive psychology of maritime health. *J Inst Remote Heal Care*. 2016;7(2):20-28.
- Ghosh S, Bowles M, Ranmuthugala D, Brooks B. 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*. Australian Maritime College; 2014:77-86.
- Albayrak T, Ziarati R. Encouraging research in maritime education & training. *J Marit Transp Eng*. 2012;1(1):4-9.
- Nikolić N, Haga JM, Tülsner J, et al. Medical training of seafarers: International Maritime Health Foundation (IMHF) Expert Panel Consensus Statement. *Int Marit Health*. 2023;74(1):15-23.
- Siedlecki SL. Understanding descriptive research designs and methods. *Clin Nurse Spec*. 2020;34(1):8-12.
- Creswell JW, Clark VLP. Choosing a mixed methods design. In: *Designing and Conducting Mixed Methods Research*. Sage Publications, Inc.; 2011:53-106.
- Wuwung L, McIlgorm A, Voyer M. Sustainable ocean development policies in Indonesia: paving the pathways towards a maritime destiny. *Front Mar Sci*. 2024;11(September):1-19. doi:10.3389/fmars.2024.1401332
- Dyagileva O, Goridko N, Popova H, Voloshynov S, Yurzhenko A. Ensuring sustainable development of education of future maritime transport professionals by means of network interaction. Published online 2020.
- Lau Y yip, Ng AKY. The motivations and expectations of students pursuing maritime education. *WMU J Marit Aff*. 2015;14:313-331.
- Nalupa HDV. Challenges and opportunities for maritime education and training in the 4th industrial revolution. Published online 2022.
- Cicek K, Akyuz E, Celik M. Future skills requirements analysis in maritime industry. *Procedia Comput Sci*. 2019;158:270-274.
- Gavalas D, Syriopoulos T, Roupis E. Digital adoption and efficiency in the maritime industry. *J Shipp Trade*. 2022;7(1):11.
- Voloshynov S, Danyk V, Yurzhenko A. Ensuring Environmental Sustainability in the Context of Innovation through High-Quality Training of Seafarers Using VR Technologies. *Seatific J*. 2024 Jul 7;4(1):31-6.
- Dewan MH, Mustafi MA, Matos F, Godina R. Exploring seafarers' knowledge, understanding, and proficiency in SEEMP: A strategic training framework for enhancing seafarers' competence in energy-efficient ship operations. *Heliyon*. 2024 Sep 15;10(17).
- Simanjuntak MB, Rafli Z, Utami SR. Enhancing Global Maritime Education: A Qualitative Exploration of Post-Internship Perspectives and Preparedness among Cadets. *J Educ Learn*. 2024;18(4):1134-46.
- Mallam SC, Nazir S, Renganayagalu SK. Rethinking maritime education, training, and operations in the digital era: Applications for emerging immersive technologies. *J Mar Sci Eng*. 2019 Nov 26;7(12):428.
- Javaid M, Haleem A, Singh RP, Suman R, Gonzalez ES. Understanding the adoption of Industry 4.0 technologies in improving environmental sustainability. *Sustain Oper Comput*. 2022 Jan 1;3:203-17.



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