EMPOWERING MARITIME PROFESSIONALS THROUGH SUSTAINABILITY TRAINING: ADDRESSING KNOWLEDGE GAPS AND INDUSTRY READINESS

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Abstract

The maritime industry is undergoing a transformative shift toward sustainability, requiring professionals to develop new competencies in green technology, emissions reduction, and regulatory compliance. However, training programs often fail to bridge the gap between theoretical sustainability education and its practical implementation in port and shipping operations. This research investigates the training and development needs of maritime professionals, lecturers, and graduates, identifying barriers to sustainability training, knowledge gaps, and industry readiness for sustainable practices. This study builds upon previous research by providing a structured analysis of sustainability education in the maritime sector, assessing the effectiveness of existing training programs and identifying gaps in institutional support. The study examines how well sustainability training prepares maritime professionals to integrate sustainability initiatives into real-world decision-making and explores strategies for enhancing workforce preparedness. A Systematic Literature Review (SLR) and qualitative analysis were conducted, involving structured interviews and questionnaires with nine stakeholders, including maritime professionals, educators, and recent graduates. Findings indicate that while sustainability training is gaining traction, industry-academic collaboration, practical learning opportunities, and institutional backing remain insufficient. This research contributes to the development of an industry-aligned sustainability training framework, offering policy recommendations for enhancing professional development in maritime sustainability. Expanding experiential learning, digital training tools, and mentorship programs will ensure maritime professionals are prepared to lead sustainable transitions in the shipping and port industries.

Keywords: Maritime Training, Sustainability Education, Professional Development, Industry Readiness, Systematic Literature Review

1. Introduction

The maritime industry stands at a crossroads where sustainability is no longer an option but an imperative. With increasing environmental regulations, digitalization, and global efforts toward green shipping and eco-friendly port management, maritime professionals face an urgent need to adapt (de la Peña Zarzuelo, 2021; Munim et al., 2020; Plaza-Hernández et al., 2021). While major shipping corporations have the resources to

implement sustainability-driven initiatives, mid-career professionals, managers, and entrepreneurs often lack the necessary training and development opportunities to incorporate sustainability effectively into their decision-making processes. This gap raises a critical question: Are current training programs in maritime education and professional development adequately equipping maritime professionals with the skills, knowledge, and competencies required for sustainable practices? Understanding the challenges professionals face in implementing sustainability is essential to designing targeted training programs that bridge existing knowledge gaps.

Maritime sustainability has evolved into a multi-dimensional concept that encompasses environmentally responsible port operations, efficient fuel consumption, emissions reduction strategies, and compliance with international regulations such as the International Maritime Organization's decarbonization agenda. However, while sustainability goals have been widely recognized, their implementation remains inconsistent across different levels of the maritime workforce. Maritime professionals, particularly officers, managers, and entrepreneurs, play a pivotal role in ensuring that sustainability policies translate into actionable industry practices (House & Saeed, 2016; Young, 1995). Yet, the training and development programs available to these professionals often fall short in providing the necessary expertise to navigate the evolving landscape of sustainability-driven decision-making. The maritime industry's transition toward sustainable practices is hindered by a lack of structured professional development programs, knowledge gaps in sustainable technology applications, and insufficient institutional support for lifelong learning initiatives.

Despite widespread discussions on the need for sustainability education in maritime institutions, the specific training needs of mid-career professionals and emerging entrepreneurs remain underexplored. While traditional maritime training has primarily focused on technical competencies such as navigation, vessel operations, and cargo management, there is limited emphasis on sustainability-focused decision-making, technology integration, and leadership in environmental compliance (Nakashima & Shibasaki, 2024). As a result, many maritime professionals struggle to align business and operational strategies with sustainability principles, leading to inefficiencies, regulatory non-compliance, and missed opportunities for innovation. The lack of sustainability literacy among decision-makers presents a major challenge, as professionals who control shipping routes, port operations, and supply chain logistics must be equipped with strategic insights into sustainability trends, green technology applications, and regulatory frameworks (Ittmann, 2017; Rahman et al., 2020).

The urgency of addressing these knowledge gaps is further amplified by the rapid evolution of sustainability-driven technologies. Green shipping technologies such as alternative fuels, energy-efficient propulsion systems, emissions monitoring software, and AI-driven vessel optimization have transformed maritime operations, but adoption remains slow due to inadequate training opportunities for professionals responsible for implementation (Prokopenko & Miśkiewicz, 2020; Raza, 2020). Without proper education on how these innovations work, how they can be integrated into existing operations, and what economic and regulatory implications they carry, maritime professionals are unable to drive sustainability efforts effectively. Additionally, entrepreneurs and startup ventures seeking to develop sustainability-focused business models face similar challenges, as they lack structured training programs that teach how to scale environmentally responsible solutions in maritime contexts.

This research seeks to address these pressing concerns by exploring how maritime professionals, educators, and recent graduates perceive sustainability training and development needs. It aims to answer the following research questions: (1) What are the key knowledge gaps among maritime professionals in implementing sustainability practices? (2) What are the primary barriers preventing maritime officers, managers, and entrepreneurs from adopting sustainable technologies? (3) How effective are current training programs in preparing professionals for sustainability-driven decision-making? (4) What training models and methodologies can be developed to enhance sustainability education for maritime professionals? By answering these questions, this study provides an evidence-based framework for restructuring maritime professional training programs to align with industry sustainability goals.

To achieve these objectives, this research employs a mixed-method qualitative approach, integrating a Systematic Literature Review (SLR) with structured interviews and questionnaires. The SLR examines previous studies on maritime sustainability education, training methodologies, and industry best practices, providing a theoretical foundation for analyzing existing gaps and challenges. It reviews global case studies, policy recommendations, and technological advancements in sustainable shipping, identifying critical themes related to workforce preparedness and industry-academic collaboration. The qualitative component of this study consists of structured interviews and questionnaires with three key stakeholder groups: (1) maritime professionals (entrepreneurs, officers, and managers), (2) maritime lecturers (educators specializing in vocational training and sustainability education), and (3) recent graduates (professionals entering the maritime workforce). By incorporating diverse perspectives from both industry and academia, this study captures a holistic understanding of training gaps, learning barriers, and the most effective educational interventions for sustainable maritime professional development.

The structured interviews and questionnaires provide valuable insights into how maritime professionals perceive their training experiences, highlighting areas where existing training programs are failing to meet industry demands. Professionals discuss challenges they face in implementing sustainability initiatives, ranging from uncertainty about regulatory changes to difficulties in securing funding for green technology investments (Farooq et al., 2020; Plaza-Hernández et al., 2021). Lecturers provide perspectives on how maritime education institutions currently integrate sustainability into curricula, revealing institutional limitations and opportunities for reform. Graduates, as individuals transitioning from education to professional practice, offer insights into the disconnect between theoretical training and real-world sustainability applications. The integration of these perspectives allows for a comparative analysis between literature-based findings and empirical industry experiences, ensuring that the research presents actionable, evidence-driven recommendations for enhancing sustainability training programs.

Findings from this study contribute to the broader discourse on maritime workforce development, offering solutions for bridging the knowledge gap between sustainability theory and industry practice. The results highlight the need for restructuring professional development programs to include more experiential learning opportunities, hands-on training with sustainable technologies, and industry-academic partnerships. Additionally, the study identifies best practices in designing maritime training programs, emphasizing the effectiveness of hybrid learning models, digital simulation-based training, and mentorship-driven education in promoting sustainability leadership. Policymakers, maritime education institutions, and industry stakeholders can leverage these findings to enhance workforce preparedness, develop targeted sustainability training initiatives, and foster a culture of environmental responsibility across all levels of maritime operations.

The significance of this research lies in its practical applications for maritime professionals, educators, and decision-makers. As the maritime sector continues to transition toward a sustainability-driven economy, it is imperative that training and development programs evolve to meet the changing needs of the workforce (Santos & Carvalho, 2020; Tijan et al., 2021). This study provides a structured framework for embedding sustainability education into maritime professional training, ensuring that current and future maritime leaders are equipped with the necessary skills, knowledge, and strategies to drive sustainability initiatives effectively. The research not only identifies existing gaps and challenges in sustainability training but also presents a roadmap for implementing comprehensive, industry-aligned educational reforms.

This research critically examines the sustainability training needs of maritime professionals, educators, and graduates, providing valuable insights into the barriers, opportunities, and strategic interventions required to enhance professional development. Through Systematic Literature Review and qualitative data analysis, the study offers empirical evidence that supports targeted training program enhancements, workforce investment in green technology education, and policy-driven learning frameworks. By fostering a well-trained, sustainability-conscious workforce, the maritime industry can achieve long-term environmental and

economic sustainability, ensuring that professionals at all levels are prepared to navigate the complexities of an evolving global industry.

2. Research Methodology

This study employs a qualitative research approach, integrating a Systematic Literature Review (SLR) and empirical data analysis through structured interviews and questionnaires. The research is designed to investigate the training and development needs of maritime professionals in implementing sustainability-driven practices within their respective organizations. By combining insights from academic literature and industry stakeholders, the study provides a comprehensive analysis of knowledge gaps, learning barriers, and strategic interventions necessary to enhance sustainability training programs for maritime professionals.

The Systematic Literature Review (SLR) serves as the foundation of this research, providing a critical evaluation of existing studies on sustainability education, professional development, and training methodologies in the maritime industry. It examines global best practices, policy recommendations, and case studies of successful sustainability training programs, identifying recurring themes related to regulatory compliance, industry-academic collaboration, and barriers to technology adoption. The literature review focuses on how current training programs address sustainability, the effectiveness of different educational models, and the extent to which maritime professionals are equipped with the necessary competencies to implement green technologies and sustainable operational strategies. By synthesizing findings from academic sources and industry reports, the SLR establishes a benchmark for assessing real-world training challenges and identifying areas where professional development programs must be improved.

In addition to the literature review, this study integrates qualitative data collection through structured interviews and questionnaires with three key stakeholder groups: maritime professionals, lecturers, and recent graduates. These stakeholders were selected based on their direct involvement in maritime operations, education, and workforce development, ensuring a multi-faceted perspective on sustainability training needs. The maritime professionals group consists of three industry experts, including officers, managers, and entrepreneurs engaged in port and shipping operations, business development, and sustainability leadership. Their insights provide a practical perspective on the challenges of implementing sustainability initiatives, technology adoption, and the role of regulatory frameworks in shaping industry practices. The lecturers group includes three educators specializing in maritime vocational training and sustainability education, offering expertise on curriculum development, academic-industry collaborations, and institutional limitations in sustainability-focused professional development. The graduates group consists of three recent maritime institute alumni who have transitioned into the workforce, providing insights into how well their academic training prepared them for sustainability-driven roles and what additional training they require to succeed in implementing green technologies and compliance strategies.

The structured interviews and questionnaires were designed to capture detailed narratives on training experiences, perceived knowledge gaps, and recommendations for improving sustainability education in maritime professional development. The questions focused on identifying barriers to sustainability adoption, assessing the effectiveness of current training programs, and evaluating preferred learning methods for maritime professionals. Participants were asked about the challenges they face in incorporating sustainability principles into daily operations, the extent to which existing training has equipped them with relevant skills, and their perspectives on the most effective training methodologies for advancing sustainability literacy in the maritime sector. By gathering qualitative data from diverse stakeholders, the study ensures a comprehensive understanding of industry expectations, educational challenges, and strategic solutions for enhancing sustainability training.

The data collected through interviews and questionnaires was analyzed using a thematic approach, categorizing stakeholder responses into key themes such as training effectiveness, barriers to sustainability learning, the role of technology in professional development, and institutional support mechanisms. The

analysis compares stakeholder perspectives to literature-based findings, identifying patterns, commonalities, and divergences between theoretical discussions and real-world experiences. The qualitative narrative approach allows for a deeper exploration of training challenges, highlighting practical insights that go beyond statistical evaluations and numerical data. By comparing industry expectations with academic training outcomes, the study assesses whether maritime professionals are adequately prepared for sustainability-driven decision-making and what improvements must be implemented to bridge the gap between education and industry needs.

The integration of SLR and qualitative data analysis strengthens the research by providing both theoretical insights and empirical evidence on sustainability training. The SLR contextualizes industry trends, policy discussions, and educational best practices, while qualitative interviews and questionnaires capture firsthand accounts of training deficiencies and professional development barriers. The combination of these methodologies ensures a holistic, well-rounded evaluation of maritime sustainability training, allowing for the formulation of practical recommendations that address both structural and educational challenges.

By applying this mixed-method approach, the research identifies key areas for improvement in maritime sustainability training, including the need for experiential learning opportunities, the role of industry-academic partnerships, and the effectiveness of hybrid learning models that integrate classroom instruction with digital simulations and real-world industry engagement (Chilisa, 2019; Creswell & Clark, 2011). The findings contribute to the development of an evidence-based framework for restructuring professional training programs, ensuring that maritime professionals are equipped with the knowledge, skills, and competencies required to implement sustainability initiatives effectively. This research methodology provides a structured approach to understanding maritime professionals' training needs, aligning industry requirements with educational reforms, and offering actionable insights for policymakers, educators, and industry leaders. Through SLR, stakeholder interviews, and thematic qualitative analysis, the study establishes a data-driven foundation for improving sustainability training programs, fostering innovation in maritime education, and supporting industry-wide efforts toward environmental responsibility and regulatory compliance.

3. Systematic Literature Review

The transition toward sustainable maritime operations is a pressing issue that requires a well-prepared workforce capable of integrating sustainability-driven decision-making into industry practices. The increasing urgency of environmental regulations, technological advancements, and market expectations for sustainability necessitates a strategic approach to professional development within the maritime sector (Issa et al., 2022; Selkou & Roe, 2022). The role of training and education in preparing maritime professionals for sustainable operations is well-documented in existing literature, yet significant gaps remain in how these training programs address the practical challenges faced by industry professionals. As sustainability requirements continue to evolve, the effectiveness of maritime training programs in equipping professionals with the necessary competencies remains a critical area of inquiry.

The literature extensively explores sustainability within maritime education and professional development, emphasizing the need for regulatory compliance, green technology adoption, and corporate social responsibility. Studies highlight that while sustainability awareness is increasing within maritime institutions, the translation of theoretical knowledge into practice remains inconsistent. Maritime education has traditionally focused on technical competencies such as ship navigation, cargo handling, and port logistics, with sustainability often treated as a supplementary topic rather than a core element of professional training. This approach results in a gap between the skills that maritime professionals need to implement sustainable practices and the knowledge they acquire during their training. A recurring theme in the literature is that professional training programs must move beyond theoretical discussions and incorporate practical learning experiences, including case studies, industry collaboration, and hands-on exposure to sustainable maritime technologies.

Regulatory frameworks play a crucial role in shaping sustainability training within maritime education. The International Maritime Organization (IMO) has introduced numerous initiatives to promote environmental responsibility in shipping, including emission reduction targets, alternative fuel regulations, and digitalization efforts (Afinowi & Nhamo, 2025; Allsop, 2009; Balkin, 2006). However, while these policies set sustainability standards, studies indicate that maritime professionals often lack the necessary training to comply effectively with these regulations. Many professionals struggle with the complexities of adapting to new sustainability-driven technologies, such as energy-efficient propulsion systems, emissions monitoring software, and AI-driven operational efficiency tools. The literature emphasizes that without adequate training, maritime professionals may perceive sustainability compliance as a regulatory burden rather than an opportunity for innovation and operational optimization. Addressing this issue requires a structured approach to sustainability training that integrates regulatory requirements with real-world application strategies.

The effectiveness of different training methodologies is widely debated in the literature, with research indicating that traditional lecture-based training methods may not be sufficient to equip professionals with the competencies required for sustainable decision-making. Instead, experiential learning models, including simulation-based training, case study analysis, and industry-academic collaborations, are considered more effective in bridging the gap between theoretical knowledge and practical application. Studies highlight successful implementations of digital simulations that allow maritime professionals to interact with real-time sustainability scenarios, enhancing their ability to make data-driven decisions in complex maritime environments. Similarly, mentorship programs and industry partnerships have been identified as essential components of sustainability training, as they provide professionals with direct access to industry experts who can guide them through the challenges of implementing sustainability initiatives.

One of the recurring gaps identified in the literature is the lack of structured sustainability education for mid-career professionals and entrepreneurs in the maritime sector. While there is substantial research on maritime training for cadets and entry-level professionals, fewer studies explore how existing professionals develop sustainability competencies throughout their careers. Many training programs are designed for regulatory compliance rather than fostering an entrepreneurial mindset for sustainability-driven innovation. This gap presents a challenge for professionals seeking to develop sustainability-focused business strategies, as they often lack access to training resources that focus on sustainability from a strategic and managerial perspective. The literature suggests that professional development programs must evolve to include training on sustainable business models, leadership in environmental responsibility, and financial management strategies for green investments.

Technology adoption is another significant theme within the literature on maritime sustainability training (Laghari et al., 2021; Plaza-Hernández et al., 2021). While digitalization and automation are revolutionizing the shipping industry, the successful adoption of these technologies depends on the ability of maritime professionals to integrate them effectively into operations. The literature suggests that many maritime professionals are not adequately trained in the technical and strategic aspects of emerging sustainability technologies. This lack of training results in underutilization of tools such as predictive analytics for fuel efficiency, AI-powered emissions tracking, and smart port management systems. Research indicates that expanding sustainability training to include digital competency development will be essential in ensuring that professionals can leverage these technologies to drive sustainability improvements in maritime operations.

A key finding in the literature is that sustainable training initiatives require greater institutional support to be effective. While some maritime training institutions have made strides in incorporating sustainability into their curricula, many remain constrained by financial limitations, outdated training infrastructure, and a lack of collaboration with industry stakeholders (Fratila et al., 2021; Zaderei, 2020). Research highlights that without adequate institutional backing, sustainability training programs struggle to provide professionals with the resources and exposure needed to apply sustainability principles in practice. To address these challenges, the literature calls for stronger industry-academic partnerships, government funding for sustainability training initiatives, and the establishment of certification programs that incentivize professionals to pursue sustainability education.

The literature also examines regional disparities in sustainability training, revealing that access to quality sustainability education varies significantly across different maritime hubs. While some regions have developed comprehensive sustainability training programs supported by policy incentives and industry collaboration, others lack structured training pathways, leaving maritime professionals without the necessary resources to engage with sustainability practices effectively. These disparities create an uneven playing field, where professionals in well-supported regions have access to cutting-edge sustainability training, while others struggle to keep pace with evolving industry standards. The literature suggests that establishing standardized sustainability training frameworks across different maritime regions will be essential in ensuring that all professionals, regardless of their location, receive the education necessary to implement sustainability best practices.

The importance of interdisciplinary sustainability training is another key insight from the literature. Many studies emphasize that sustainability education should not be limited to technical and operational aspects but should also incorporate elements of environmental science, business strategy, and policy analysis. Training programs that take an interdisciplinary approach provide maritime professionals with a broader understanding of how sustainability intersects with economic and regulatory considerations, allowing them to develop more comprehensive and effective sustainability strategies. Some research suggests that sustainability training should also include behavioral and cultural change components, as shifting mindsets and attitudes toward sustainability is just as crucial as imparting technical knowledge.

The findings from this literature review highlight the need for a restructured approach to sustainability training for maritime professionals. While existing research acknowledges the importance of sustainability education, there is a consensus that current training programs are insufficient in preparing professionals for the challenges of implementing sustainability initiatives in practice. The literature underscores the need for training programs that go beyond compliance-based education and focus on equipping professionals with the skills to lead sustainability-driven transformations in their organizations. Integrating technology-driven learning models, expanding access to sustainability training for mid-career professionals, and fostering stronger industry-academic collaborations are identified as key solutions to enhancing the effectiveness of sustainability training.

This systematic literature review provides a foundation for the research by identifying key challenges and opportunities in maritime sustainability training. By synthesizing insights from global studies on training methodologies, regulatory frameworks, and industry best practices, the review establishes a framework for understanding how sustainability education can be improved for maritime professionals. The literature confirms that effective sustainability training requires a combination of experiential learning, digital competency development, and institutional support. These findings support the qualitative research component of the study, which seeks to explore how maritime professionals, lecturers, and graduates perceive the effectiveness of sustainability training and what improvements are needed to enhance professional development in sustainability-driven maritime operations. Through this research, a structured and actionable framework for sustainability training can be developed, ensuring that maritime professionals are equipped with the necessary knowledge, skills, and resources to drive meaningful sustainability transformations in the industry.

4. Results and Discussion

The research findings indicate that sustainability training for maritime professionals is both effective and highly relevant, yet significant challenges remain in bridging knowledge gaps, improving training methodologies, and ensuring institutional support. The qualitative analysis of industry professionals, educators, and graduates reflects a strong alignment with the objectives outlined in the Systematic Literature

Review (SLR). Maritime professionals, particularly officers, managers, and entrepreneurs, demonstrate a strong recognition of the need for sustainability-driven training, as reflected in the consistently high scores across key indicators. Lecturers, responsible for shaping maritime education curricula, express concerns over institutional limitations and the need for more structured collaborations between academia and industry. Graduates, who recently transitioned from vocational training to industry roles, provide critical insights into the gap between theoretical instruction and practical sustainability implementation.

The highest-rated indicator, "Knowledge Gaps in Sustainable Maritime Practices," received an overall score of 4.6, with maritime professionals rating it at 4.7, indicating that industry leaders acknowledge a strong need for sustainability-focused upskilling. Educators provided a similar assessment at 4.6, affirming that current curricula do not adequately equip professionals with the necessary competencies in green shipping, emissions reduction, and regulatory adaptation. Graduates rated this indicator at 4.5, reflecting their struggles in translating academic sustainability concepts into real-world applications. This finding reinforces the need for training programs that integrate sustainability education with hands-on, experiential learning opportunities.

The effectiveness of current training programs was rated 4.5 overall, demonstrating a positive perception of existing training models while also highlighting areas for enhancement. Maritime professionals rated it 4.6, emphasizing the value of sustainability-oriented workshops, simulations, and on-the-job training. Lecturers, who scored this indicator at 4.5, recognized the growing institutional efforts to embed sustainability into maritime education but acknowledged gaps in interdisciplinary training. Graduates, with a score of 4.3, suggested that while sustainability is increasingly discussed in academic settings, its implementation in structured training programs remains inconsistent.

"Barriers to Sustainability Technology Adoption" was rated at 4.3 overall, with maritime professionals scoring it 4.5, lecturers at 4.3, and graduates at 4.2. This reflects industry-wide challenges in integrating advanced sustainability technologies, such as AI-driven energy optimization, digital emissions tracking, and alternative fuel implementation. The relatively lower scores by lecturers and graduates suggest that while technological innovation is widely recognized as essential, training programs do not provide sufficient exposure to real-world applications.

"Industry Readiness for Sustainability Implementation" was rated 4.2 overall, with maritime professionals rating it 4.4, lecturers at 4.2, and graduates at 4.1. These results indicate that while maritime industries are aware of sustainability imperatives, implementation is hindered by workforce preparedness gaps and slow technology adoption. The lecturers' rating of 4.2 suggests a disconnect between industry expectations and educational outputs, reinforcing the need for policy interventions and industry-academic collaborations.

The lowest-rated indicator, "Institutional Support for Sustainability Training," received an overall score of 4.1, with maritime professionals rating it 4.3, lecturers at 4.1, and graduates at 4.0. This suggests that while sustainability training is gaining traction, institutional backing remains insufficient in terms of funding, policy incentives, and infrastructure for professional development. Graduates' lowest rating of 4.0 highlights a lack of formal mentorship programs, startup incubators, and structured career pathways for sustainability-oriented professionals.

The following table presents a detailed breakdown of the research results:

Comprehensive Research Results on Maritime Sustainability Training

Indicator	Maritime Professionals (Experts)	Maritime Lecturers (Educators)	Maritime Graduates (Recent Workforce)	Overall Score
Knowledge Gaps in Sustainable Maritime Practices	4.7	4.6	4.5	4.6
Effectiveness of Current Training Programs	4.6	4.5	4.3	4.5
Barriers to Sustainability Technology Adoption	4.5	4.3	4.2	4.3
Industry Readiness for Sustainability Implementation	4.4	4.2	4.1	4.2

Institutional Support for Sustainability Training	4.3	4.1	4.0	4.1

Analysis and Interpretation

The results closely align with the Systematic Literature Review, which emphasizes that while awareness of sustainability in the maritime sector is increasing, training structures remain fragmented and inconsistent. The high rating for knowledge gaps (4.6 overall) reflects what the literature suggests: that sustainability education is still emerging and requires a more structured, competency-based approach. The challenges in technology adoption (4.3 overall) reinforce previous findings that many maritime professionals lack hands-on exposure to advanced sustainability technologies, limiting their ability to integrate them effectively into operations.

The SLR highlighted that digital transformation and regulatory shifts are key drivers of sustainability in maritime industries, which is strongly reflected in the data. Maritime professionals and lecturers consistently rated training effectiveness and industry readiness above 4.2, demonstrating a positive perception of ongoing improvements in sustainability training. However, graduates consistently rated indicators lower than professionals and lecturers, suggesting that educational institutions have not fully adapted their curricula to provide experiential sustainability learning.

A key divergence between literature-based findings and empirical results is the institutional support indicator, which received the lowest overall rating of 4.1. The literature emphasizes the importance of government and industry-backed training initiatives, yet the empirical findings suggest that these initiatives remain underfunded and inconsistently applied across different regions. The low scores from graduates (4.0) further reinforce this issue, as new entrants into the industry struggle with limited access to sustainability-focused mentorship programs, startup funding, and structured career pathways.

One of the most critical takeaways from this research is the need for targeted sustainability training frameworks that combine theoretical instruction with applied, hands-on learning. The SLR supports the idea that maritime training institutions should adopt experiential learning models, such as simulations, on-site industry training, and case-based learning methodologies. This study's findings further validate this, as graduates expressed dissatisfaction with current training programs' lack of practical sustainability applications.

The study also highlights the need for interdisciplinary sustainability training that extends beyond technical knowledge to include business strategy, policy comprehension, and environmental leadership. Maritime professionals consistently emphasized that sustainability is not just a technical challenge but also a strategic and regulatory issue, requiring integrated learning approaches that prepare professionals to navigate industry complexities (Berg, 2013; Christodoulou-Varotsi & Pentsov, 2008). The results support expanding maritime training programs to incorporate financial literacy, policy frameworks, and sustainability entrepreneurship.

The findings of this study confirm that while sustainability training in the maritime industry has gained momentum, there remain significant gaps in knowledge application, technological readiness, and institutional support. Maritime professionals and lecturers generally agree that sustainability education is improving, but graduates highlight persistent challenges in applying theoretical concepts to industry practice (Sharma et al., 2019). The study reinforces the need for expanded sustainability-focused curricula, improved institutional backing, and industry-academic collaborations. By addressing these gaps, policymakers, educators, and industry leaders can develop comprehensive training models that enhance workforce preparedness, promote sustainability leadership, and drive long-term environmental responsibility in the maritime sector.

5. Conclusion

This research highlights the critical need for structured sustainability training in the maritime sector, focusing on how maritime professionals, lecturers, and graduates perceive sustainability education and its practical applications. The findings confirm that while sustainability awareness is increasing, knowledge gaps, limited institutional support, and barriers to technology adoption continue to hinder the effective implementation of

sustainability initiatives in port and shipping industries. Maritime professionals acknowledge the importance of sustainability-driven training, but the results indicate that current training programs do not fully equip them with the necessary skills for real-world sustainability decision-making. Lecturers emphasize curriculum gaps and the need for industry-academic collaboration, while graduates express difficulties in applying theoretical sustainability concepts to professional practice. The study aligns with the Systematic Literature Review, which suggests that experiential learning, industry partnerships, and digital training tools are key to enhancing sustainability education. However, institutional backing remains inadequate, as reflected in the lowest-rated indicator for sustainability training support. Addressing these gaps requires policy-driven reforms, interdisciplinary sustainability curricula, and expanded mentorship programs. This research contributes to the development of a structured framework for sustainability training in maritime education, offering practical recommendations for policymakers, educators, and industry leaders. Strengthening professional training, increasing access to sustainability-focused resources, and fostering innovation-driven learning will ensure that maritime professionals are prepared to lead the industry's transition toward sustainable operations.

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