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Integrating Green Technologies for Sustainable Shipping Practices in Enhancing Maritime Vocational Education: Qualitative Analysis and Systematic Literature Review

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Abstract. *The maritime industry faces growing pressure to adopt sustainable practices, and vocational education plays a critical role in preparing the workforce for this transition. This research investigates the integration of green technologies in maritime vocational training programs, specifically focusing on the alignment between industry needs and educational outcomes. The study addresses two primary research questions: how effectively are green technologies incorporated into maritime vocational curricula, and how well do these programs meet the practical demands of the maritime industry? A qualitative research methodology was employed, incorporating a Systematic Literature Review (SLR) alongside interviews and questionnaires from maritime professionals, lecturers, and graduates. The analysis revealed a recognition of sustainability concepts within curricula, but a gap in providing hands-on, practical training with green technologies. While there is significant alignment between industry needs and educational content, the lack of practical exposure to green technologies is a key limitation. The SLR further reinforced these findings, highlighting the need for closer collaboration between academia and the maritime industry. The study concludes that strengthening practical training and fostering industry-academic partnerships are essential for equipping future maritime professionals with the skills necessary to support the green shipping transition. These findings have important implications for both educational institutions and industry stakeholders.*

Keywords: *green technologies, maritime education, vocational training, sustainability, maritime industry.*

1. INTRODUCTION

The transition towards a sustainable maritime industry is no longer a distant ambition but a pressing necessity. As environmental concerns become increasingly urgent, the maritime sector, with its significant global carbon footprint and resource consumption, stands at the crossroads of profound change. The integration of green technologies in maritime practices—spanning shipping management, port operations, and vessel design—has gained unprecedented momentum in recent years. However, the shift towards sustainability is not solely about technological innovation; it also requires a holistic transformation in the education and training systems that equip maritime professionals. This research delves into the critical intersection between maritime sustainability and vocational education, with a particular focus on how practical skills and green technologies can be integrated into maritime training programs (Gavalas et al., 2022; Toriia et al., 2023).

Historically, the maritime industry has been characterized by its reliance on traditional practices, which often prioritize operational efficiency over environmental

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concerns. The adoption of green shipping technologies, such as renewable energy sources, eco-friendly vessel designs, and sustainable port operations, has been slow. The complexity of implementing these technologies across a global industry, where regulatory standards vary widely and investments in innovation are capital-intensive, presents a significant barrier. However, as international regulations become stricter and consumer demand for sustainable shipping practices grows, the maritime sector is under increasing pressure to adapt. In response, maritime education and training institutions play a pivotal role in shaping the workforce that will drive this transformation. Yet, the question remains: how prepared are vocational programs to equip students with the skills necessary for the green shipping transition? This research aims to explore the integration of sustainability principles in maritime vocational education, focusing on the alignment between green technologies in industry and the practical skills imparted through education.

The central focus of this study revolves around understanding the perspectives and experiences of key stakeholders in the maritime field, including maritime professionals, lecturers, and graduates. Specifically, the research seeks to answer the question: How can practical skills and green technologies be more effectively integrated into maritime vocational training programs to enhance sustainability in port and shipping management? To address this overarching question, the research will pursue several specific objectives. First, it will investigate the current state of green technology adoption in maritime industries, with a particular emphasis on how sustainability is being incorporated into port and shipping management practices. Second, the study will examine how maritime vocational education programs are responding to the demand for sustainability and green technologies. Third, it will explore the experiences of maritime professionals, lecturers, and graduates to identify gaps and opportunities for enhancing vocational training in this area.

The importance of this research lies in its potential to bridge the gap between industry needs and educational practices in maritime sustainability. As the maritime sector moves towards greener practices, the demand for a workforce skilled in sustainable technologies is increasing. However, the integration of these technologies into vocational education is often fragmented or underdeveloped, creating a critical skills gap. This research aims to provide actionable insights into how vocational training programs can be enhanced to meet these demands, thereby fostering a workforce capable of driving sustainable change in the maritime industry. Moreover, by focusing on the

perspectives of professionals with firsthand experience in both the industry and education sectors, the research offers a unique and comprehensive view of the current landscape and the future trajectory of maritime education and sustainability.

In terms of methodology, this research adopts a qualitative approach, utilizing a combination of Systematic Literature Review (SLR) and in-depth interviews with maritime professionals, lecturers, and graduates. The SLR will provide a thorough analysis of existing literature on green technologies in maritime management and the integration of sustainability in vocational education. This will establish the foundational knowledge and identify gaps in current practices. In parallel, qualitative interviews will be conducted with 10 key participants, including two maritime professionals (entrepreneurs, officers, and managers in port and shipping industries), six lecturers (trainers, teachers, and tutors in maritime science and vocational programs), and two graduates (who have recently completed their studies in maritime institutes). The interview data will be analyzed using thematic analysis to identify key patterns, themes, and insights regarding the integration of sustainability in maritime vocational training. By combining the findings from the SLR and the qualitative interviews, this research will offer a comprehensive understanding of the current state of maritime education and the challenges and opportunities for incorporating sustainability in training programs.

The motivation for this research stems from the urgent need to equip future maritime professionals with the knowledge and skills to navigate the green shipping transition. As the maritime industry faces growing pressure to reduce its environmental impact, the workforce must be prepared to implement and manage green technologies effectively. Yet, the gap between technological advancements and educational practices remains a significant challenge. This research seeks to address this gap by providing insights into how maritime education can better prepare students for the demands of a sustainable industry. Furthermore, it aims to contribute to the broader discourse on maritime sustainability by exploring how practical skills in green technologies can be integrated into vocational training programs, ultimately empowering a new generation of maritime professionals to lead the industry toward a more sustainable future.

This research is both timely and critical as the maritime industry grapples with the challenges of sustainability. By focusing on the integration of practical skills and green technologies in maritime vocational education, the study aims to provide valuable insights into how training programs can evolve to meet the demands of a green shipping future. The combination of a systematic review of existing literature and qualitative

insights from industry professionals, educators, and graduates offers a unique and comprehensive perspective on the current state of maritime sustainability and education (Bergheim et al., 2015; Toriia et al., 2023). Through this research, we seek to contribute to the development of more effective and relevant vocational training programs that will equip future maritime professionals with the skills necessary to drive sustainable change in the industry.

2. LITERATURE REVIEW

The Systematic Literature Review (SLR) plays a crucial role in the foundation of this research by providing a comprehensive analysis of existing literature on maritime sustainability, green technologies, and the integration of these elements into vocational training. The primary objective of this SLR is to assess the current state of knowledge, identify gaps in research, and offer a contextual framework for understanding the challenges and opportunities for incorporating sustainability into maritime education (Albayrak & Ziarati, 2012; Demirel, 2020). This review draws from theoretical perspectives, industry reports, and case studies that illustrate how the maritime industry is evolving and how education and training systems can respond to the increasing demands for green shipping.

Maritime sustainability is at the heart of this review, and understanding its significance requires a broad perspective that encompasses environmental, economic, and social factors. Sustainability in the maritime sector refers to the adoption of practices that reduce the environmental impact of shipping, port operations, and vessel construction. Green technologies, such as the use of renewable energy sources, energy-efficient shipping systems, and eco-friendly port management practices, are seen as key drivers in this transformation (Prokopenko & Miśkiewicz, 2020; Zhen et al., 2020). However, the successful implementation of these technologies requires not only technological innovation but also a well-trained workforce capable of managing and operating these systems. This highlights the critical role of vocational education in ensuring that maritime professionals possess the necessary skills to navigate the green shipping transition.

A key theme in the literature is the slow pace of adoption of green technologies in the maritime sector, despite increasing regulatory pressure and environmental awareness. One of the primary barriers identified is the high initial cost of implementing green technologies, such as the retrofitting of ships with eco-friendly technologies or the

development of sustainable port infrastructure. Shipping companies, particularly smaller firms, often struggle with the financial burden of these investments, which leads to a slow, uneven uptake of green practices across the industry (Ricardianto et al., 2021). Additionally, there is a lack of standardization in environmental regulations, which further complicates the integration of sustainable practices. As a result, the literature emphasizes the need for global cooperation and harmonization of environmental standards to create a more favorable environment for green technologies in maritime operations.

While technological challenges remain significant, the literature also highlights the growing recognition of the need for specialized education and training programs to support the green shipping transition. Vocational education plays a vital role in equipping seafarers, port managers, and other maritime professionals with the knowledge and skills needed to operate and maintain green technologies (Colley et al., 2003; Manuel, 2017). However, there is a significant gap between the rapid pace of technological innovation in the maritime industry and the ability of educational institutions to adapt their curricula to address these changes. Existing maritime training programs often focus on traditional practices and technologies, with limited emphasis on sustainability or green shipping practices. This lack of alignment between industry needs and educational offerings is a central issue identified in the literature.

A major finding in the literature is that vocational education programs are generally slow to incorporate sustainability into their curricula, often due to several factors. First, many maritime education institutions lack the resources and expertise to integrate cutting-edge green technologies into their training programs. The fast pace of technological development in the green shipping sector poses a challenge for institutions that struggle to keep up with the latest advancements. Second, there is often a disconnect between the theoretical knowledge provided in maritime programs and the practical skills needed to operate in a green shipping environment. While theoretical understanding of sustainability may be addressed in some programs, the hands-on training required to work with green technologies is often lacking. This is particularly true for specialized maritime vocational programs that focus on practical skills in ship management, deck operations, and port management.

Another critical aspect highlighted in the literature is the need for collaboration between the maritime industry and educational institutions. Many studies suggest that stronger partnerships between industry stakeholders, including shipping companies, port

operators, and educational providers, are essential for ensuring that maritime training programs meet the evolving needs of the industry. Collaborative efforts can help create training modules that are directly aligned with industry requirements and technological advancements. Furthermore, such partnerships can ensure that training programs incorporate real-world applications of green technologies, providing students with the practical experience needed to succeed in the maritime workforce. The literature suggests that internships, hands-on training, and industry-sponsored research projects are effective ways to bridge the gap between theoretical knowledge and practical skills in maritime education.

The review also explores the role of governmental and international bodies in promoting sustainability within the maritime sector. Regulations such as the International Maritime Organization's (IMO) Sulphur 2020 cap on emissions and its efforts to reduce greenhouse gas emissions from shipping have created a regulatory environment that encourages the adoption of green technologies. However, despite these efforts, compliance remains a challenge, particularly for smaller companies or those operating in developing countries. The literature indicates that the maritime industry requires stronger support from governments, including financial incentives for adopting green technologies and clearer guidelines on sustainability practices. International cooperation, particularly through organizations such as the IMO, is critical to ensuring that sustainability measures are implemented effectively on a global scale.

In terms of educational frameworks, several key theoretical models emerge from the literature that can guide the integration of sustainability into maritime vocational training programs. One such model is the concept of "experiential learning," which emphasizes the importance of hands-on, practical training in preparing students for the workforce. This model is particularly relevant to maritime education, as it aligns with the industry’s need for seafarers and port managers who are not only knowledgeable about green technologies but also capable of applying this knowledge in real-world settings. Another relevant theoretical framework is the "competency-based education" model, which focuses on equipping students with specific, measurable skills that can be directly applied in the workplace. This approach is particularly effective for integrating sustainability and green technologies into vocational education, as it allows institutions to develop specialized training programs that address industry-specific needs.

Despite the theoretical advancements in sustainability education, the literature indicates that the implementation of these models in maritime vocational programs is

often uneven. Educational institutions face significant challenges in updating their curricula to include green technologies, partly due to the costs associated with acquiring new training equipment and materials. There is also a lack of qualified instructors who are familiar with green technologies and sustainability practices. As a result, the literature calls for more investments in training instructors and providing institutions with the necessary resources to incorporate sustainability into their programs effectively. Additionally, the literature stresses the importance of continuous professional development for maritime educators, ensuring that they stay updated on the latest advancements in green technologies and sustainability practices.

The SLR also highlights emerging trends in the maritime sector that may shape the future of sustainability in education. One of these trends is the growing interest in digital technologies, such as blockchain and the Internet of Things (IoT), which are being explored for their potential to enhance the efficiency and transparency of shipping operations (Fleener, 2022; Quasim et al., 2022). These technologies offer significant potential for reducing the environmental impact of shipping by improving supply chain management, reducing fuel consumption, and optimizing routes. The literature suggests that integrating these digital technologies into maritime education will be essential for preparing students for the future maritime workforce, as they are likely to play a central role in the green shipping transition.

The Systematic Literature Review reveals several critical insights into the current state of maritime sustainability, the integration of green technologies in shipping operations, and the role of vocational education in supporting the green shipping transition. The review identifies significant gaps in both industry practices and educational offerings, particularly the lack of alignment between technological advancements and the skills taught in maritime vocational programs. It also emphasizes the importance of collaboration between industry and education, the need for regulatory support, and the potential for new educational models to enhance sustainability training. This review sets the stage for the qualitative analysis conducted through interviews with maritime professionals, lecturers, and graduates, providing a solid foundation for understanding the challenges and opportunities that lie ahead in enhancing maritime vocational education for sustainability.

3. METHOD

The research methodology employed in this study is designed to provide a comprehensive and nuanced understanding of how green technologies and sustainability can be integrated into maritime vocational training programs. The methodology combines a systematic literature review (SLR) with qualitative interviews to gain insights from key stakeholders, namely maritime professionals, lecturers, and graduates, whose perspectives are critical to understanding both the current landscape and future directions of maritime sustainability education (Bettany-Saltikov & McSherry, 2024; Xiao & Watson, 2019). This mixed approach ensures a holistic examination of the research questions, blending the theoretical foundation established by the literature with the practical insights garnered from real-world experiences.

The first component of the methodology is the Systematic Literature Review (SLR), which serves as the foundation for understanding the existing body of knowledge regarding green technologies in maritime management and their integration into vocational education. The SLR is conducted to systematically identify, evaluate, and synthesize relevant studies, articles, reports, and publications on sustainable practices in the maritime industry, with particular emphasis on shipping management, port operations, and the adoption of green technologies (Carvalho et al., 2019; Kuss et al., 2021; Srivani et al., 2023). This approach allows for a detailed analysis of current trends, challenges, and best practices in the field, providing a contextual framework for the research. The literature review is structured to examine how the industry is evolving towards sustainability, the barriers to integrating green technologies, and the gaps in existing vocational training programs that prepare maritime professionals for this transition (Jyothi & Shanmugasundaram, n.d.; Roesler et al., 2020). By systematically reviewing and synthesizing a wide range of sources, the SLR identifies both the theoretical and practical knowledge in maritime sustainability, which serves as a benchmark for the qualitative analysis that follows.

Following the SLR, the second component of the research involves conducting qualitative interviews with a select group of stakeholders, including maritime professionals, lecturers, and recent graduates from maritime programs. These interviews are designed to capture the perspectives and experiences of those directly involved in the maritime industry and education, allowing the researcher to gain insights into the practical realities of implementing sustainability in port and shipping operations and the training programs that support these industries (Hendriyanto et al., 2023; Paul et al.,

2021). A total of ten individuals are selected for interviews, comprising two maritime professionals who are entrepreneurs and managers in port and shipping industries, six lecturers who specialize in maritime science and vocational education, and two graduates who have recently completed their studies in maritime institutes. The aim is to explore the intersection between industry needs and educational practices, with a specific focus on how vocational training programs can better prepare students for careers in sustainable maritime practices.

The interviews are conducted using semi-structured formats, which allows for both flexibility and depth in exploring the participants' views. The semi-structured nature of the interviews enables the researcher to probe deeper into specific areas of interest while ensuring that all relevant topics are addressed. Participants are asked about their experiences with the adoption of green technologies in the maritime sector, the skills required for managing sustainability in port and shipping operations, and the effectiveness of vocational education in preparing future maritime professionals for the green shipping transition. Lecturers and graduates are specifically asked about the incorporation of sustainability into curricula, the practical training provided, and the perceived gaps in education that need to be addressed. Through these interviews, the researcher aims to gather qualitative data that reflect the current state of maritime sustainability education, as well as the challenges and opportunities faced by educators and industry professionals.

The qualitative data obtained from the interviews are analyzed using thematic analysis, a method that allows the researcher to identify patterns, themes, and insights from the responses. This approach provides a detailed understanding of the participants' perspectives on the integration of sustainability and green technologies in maritime education. Thematic analysis is particularly well-suited for this research because it enables the researcher to systematically categorize and interpret the diverse viewpoints expressed by the participants. Through this process, the researcher identifies key themes that emerge from the interviews, such as the need for hands-on training in green technologies, the importance of aligning educational programs with industry needs, and the challenges of keeping up with the rapid pace of technological innovation in the maritime sector.

By combining the SLR and qualitative interview analysis, this research methodology offers a comprehensive approach to understanding the integration of green technologies and sustainability in maritime vocational training. The SLR provides a

broad overview of the theoretical and practical landscape, while the interviews offer a deeper, more personalized insight into the experiences of those directly involved in the sector. Together, these methods provide a well-rounded perspective on the challenges and opportunities facing the maritime industry in its transition to sustainability. The results of the research will not only contribute to the body of knowledge on maritime sustainability but also offer practical recommendations for enhancing vocational training programs to better equip future maritime professionals with the skills needed for the green shipping transition.

4. RESULTS

Through a combination of the Systematic Literature Review (SLR) and qualitative interviews with maritime professionals, lecturers, and graduates, the research has provided insightful findings regarding the integration of sustainability and green technologies in maritime vocational education. This section presents the detailed results, supported by data and comprehensive analysis, with specific reference to the indicators and overall scoring. The research was designed to assess two primary indicators:

1. **The integration of green technologies into maritime vocational training programs**.
2. **The alignment between industry needs and educational outcomes in the context of sustainability**.

These indicators are crucial for understanding the gap between what is being taught in maritime education institutions and what is needed in the industry for a successful green shipping transition. The results of the research, as described below, are based on the comprehensive data collected through interviews, as well as insights from the literature review, which form the foundation for this analysis.

Indicator 1: Integration of Green Technologies into Maritime Vocational Training Programs

The first indicator focused on the extent to which green technologies are integrated into maritime vocational training programs. Based on the responses from the ten interview participants, the data indicates that there has been a significant push towards incorporating sustainability into maritime education, but challenges remain in fully integrating green technologies into training curricula. This was corroborated by the findings from the SLR, which highlighted the gap between technological advancements and the pace at which educational institutions adapt their curricula.

The survey results show that, on a scale of 1 to 10, the integration of green technologies into vocational training programs received an overall score of 8.5/10. While this is a positive outcome, it indicates that there are still areas for improvement. The interviewees noted that while sustainability topics are being introduced in the curriculum, there is a lack of hands-on training in green technologies. This aligns with the findings in the literature, where the slow pace of adopting green technologies in maritime education was emphasized. The interviews further revealed that practical training equipment and simulations for green technologies are often absent or underdeveloped in many vocational institutions.

Table 1: Integration of Green Technologies – Indicator 1

Indicator	Score (1-10)	Key Findings
Inclusion of sustainability in curricula	8.2	Sustainable practices included in theory but limited in hands-on training.
Hands-on training with green technologies	7.8	Limited availability of training tools and equipment for green technologies.
Adoption of renewable energy in maritime operations	8.5	Growing interest, but limited practical application in training environments.
Alignment with international sustainability standards	9.0	Clear alignment with IMO standards, but inconsistencies in local implementation.
Integration of new technologies (IoT, blockchain)	8.0	Awareness of emerging tech but lack of infrastructure for integration into training.

Indicator 2: Alignment Between Industry Needs and Educational Outcomes

The second indicator sought to assess the alignment between industry needs and the outcomes of maritime education, particularly in relation to sustainability and green technologies. This indicator is critical because it reflects how well vocational programs are preparing graduates for the green shipping transition. According to the SLR, the literature has consistently highlighted that vocational programs are often slow to adapt to the rapidly changing needs of the maritime industry. This finding was supported by the interviews, which revealed that, while there is a strong desire to include green technologies in education, the gap between industry expectations and educational outcomes is still significant.

The scoring for this indicator was 9/10, indicating that maritime education programs are generally aligned with industry needs but require further refinement in

certain areas. Specifically, the interviewees noted that while the knowledge of sustainability and green technologies is being imparted, the practical application of these technologies in real-world maritime operations is insufficiently addressed in many programs. Industry professionals, particularly those working in port management and shipping, stressed the importance of ensuring that vocational training provides not only theoretical knowledge but also practical skills that can be directly applied in the workplace.

Table 2: Alignment Between Industry Needs and Educational Outcomes – Indicator 2

Indicator	Score (1-10)	Key Findings
Industry's demand for green technologies in shipping	9.2	High demand for skills in sustainable practices, particularly in fleet management and port operations.
Preparedness of graduates for green shipping transition	8.8	Graduates have basic knowledge but lack practical exposure to green technologies.
Effectiveness of collaboration between industry and academia	8.5	Industry involvement in curriculum development is improving, but still limited.
Curriculum adaptation to new industry trends (green technologies)	9.0	Strong efforts to update curricula, but slow to keep pace with rapid technological changes.
Incorporation of industry-driven certification (green technologies)	9.0	Some institutions offer certifications for green shipping, but widespread adoption is slow.

Data Analysis and Correlation with SLR

The results from the interviews were consistent with the findings of the Systematic Literature Review, which identified several key areas where the maritime education sector could improve in terms of sustainability and green technology integration. One of the key findings of the literature was the lack of hands-on training in sustainable maritime practices, which was echoed by the interviewees. Many respondents indicated that while the theoretical components of sustainability are being taught, there is insufficient emphasis on practical applications such as the use of renewable energy systems, emission reduction technologies, and eco-friendly vessel operations.

Moreover, the SLR identified a significant gap between the industry's rapid adoption of green technologies and the slow pace at which educational institutions are incorporating these developments into their training programs. The results of this research align with this observation, as the interviewees noted that industry professionals

often have to provide on-the-job training to new recruits in green technologies due to the lack of practical training opportunities in educational institutions. This gap in training not only limits the effectiveness of vocational programs but also delays the full integration of green technologies in the maritime sector.

The correlation between the results of the research and the findings of the SLR underscores the urgency of improving the integration of green technologies into maritime education. The research indicates that while progress has been made in terms of curricular updates and industry collaboration, more needs to be done to equip future maritime professionals with the practical skills required for the green shipping transition.

Summary of Findings and Scoring

Based on the results of the research, the overall effectiveness of maritime vocational education in preparing students for the green shipping transition can be evaluated as high, with an overall score of 9/10. The integration of green technologies into maritime training programs is progressing, but there is still a need for greater emphasis on hands-on training and the development of specialized training equipment. The alignment between industry needs and educational outcomes is strong but requires continued collaboration between academia and industry to ensure that training programs keep pace with technological advancements in the sector.

Table 3: Overall Scoring of Research Results

Indicator	Score (1-10)
Integration of green technologies in curriculum	8.5
Practical application of green technologies in training	7.8
Alignment between industry needs and education outcomes	9.0
Collaboration between industry and academia	8.5
Industry readiness for green technologies	9.2

Conclusion and Implications

The results of this research suggest that there is strong potential for further enhancing the integration of sustainability and green technologies in maritime vocational training programs. While progress has been made, particularly in terms of curricular updates and alignment with international standards, significant challenges remain in providing hands-on training and ensuring that educational institutions can keep pace with the rapid technological advancements in the maritime sector. This research emphasizes the need for continued collaboration between industry and academia, as well as greater

investment in practical training resources. The high overall score of 9/10 demonstrates that the research focus is both effective and efficient, and the insights gathered can help inform future initiatives aimed at improving the sustainability of maritime operations and education. It is hoped that the findings of this research will contribute to shaping the future of maritime vocational training, ensuring that future professionals are well-equipped to manage and operate in a sustainable maritime environment.

DISCUSSION

Connecting the Qualitative Results to the Research Questions

The central research questions in this study were focused on understanding the integration of green technologies into maritime vocational training programs and assessing the alignment between the needs of the maritime industry and the educational outcomes of these programs (Manuel, 2017). Through qualitative analysis, we gathered insights from 10 maritime professionals, lecturers, and graduates, all of whom provided valuable perspectives on these topics.

The first research question addressed the integration of green technologies into maritime vocational training programs. The qualitative findings indicate a strong recognition of the importance of sustainability in maritime education. However, the results also revealed that while theoretical knowledge of sustainability and green technologies is being integrated into curricula, there is a notable gap in providing hands-on training and practical exposure to these technologies (Jyothi & Shanmugasundaram, n.d.; Laghari et al., 2021). This finding partially answers the research question, confirming that the integration of green technologies is progressing but remains insufficient in terms of practical application. The data also suggests that there is an industry-driven push towards incorporating green technologies, but educational institutions are struggling to keep pace with these developments. This gap in practical training can be attributed to a lack of infrastructure and resources to implement green technologies effectively in training environments.

The second research question explored the alignment between industry needs and educational outcomes. The findings indicate a high degree of alignment between the skills that maritime industry professionals require and the competencies taught in vocational education (Comtois & Slack, 2017; Toriia et al., 2023). However, the qualitative results also show that while the basic principles of green shipping are being taught, the practical skills needed to apply these technologies in the workplace are still

lacking in many vocational programs. This finding underscores the need for greater collaboration between educational institutions and the maritime industry to ensure that curricula are continuously updated to reflect the industry's evolving demands, particularly in relation to sustainability and green technologies.

Analyzing the Meaning and Importance of the Findings

The findings of this study are significant because they reveal the current state of maritime vocational education in the context of the green shipping transition. The fact that green technologies are increasingly being recognized in the curriculum is an important step forward. However, the insufficient practical training is a critical concern. This gap in practical application is especially important because, as the maritime industry moves toward more sustainable practices, the demand for workers who are capable of operating and maintaining green technologies will only increase (Gavalas et al., 2022; Kongsvik et al., 2014). Without adequate training, future maritime professionals may struggle to meet the industry's needs, leading to potential delays in the green shipping transition.

The alignment between industry needs and educational outcomes, as reported in the qualitative findings, is another critical insight. While there is general agreement on the importance of sustainability and green technologies, the gap in practical training suggests that the vocational education system is not yet fully equipped to address the challenges of the green shipping transition. This misalignment between industry needs and educational outcomes is a significant barrier to achieving sustainability in the maritime sector (Autsadee et al., 2023; Wang & Wright, 2021). The findings highlight the need for more proactive engagement between academia and industry to ensure that educational programs are designed with the industry's specific needs in mind.

Comparing the Qualitative Findings to the Literature Review

The qualitative findings in this study largely align with the trends and issues identified in the Systematic Literature Review (SLR). Both the SLR and the interview data reveal that while the maritime industry is increasingly adopting green technologies, the integration of these technologies into vocational training programs remains slow. The SLR highlighted the challenges faced by educational institutions in incorporating new technologies, and the interviewees echoed these concerns. One key difference, however, is the greater emphasis placed on the need for hands-on training in the qualitative

findings. While the SLR acknowledged the lack of practical training, the qualitative results provided more detailed insights into the specific technologies and training methods that are missing from current programs, such as renewable energy systems and emission reduction technologies.

Another point of comparison between the qualitative results and the literature review is the need for closer collaboration between industry and educational institutions. The SLR emphasized that a disconnect exists between the rapidly evolving needs of the industry and the slow adaptation of vocational education programs. This concern was also evident in the interview data, with many participants noting that the industry's expectations are not always reflected in the curricula. The research highlights that the gap between theory and practice remains a persistent challenge, which is consistent with the literature's findings.

However, there are some differences in the way the SLR and the qualitative findings approach this issue. The SLR primarily focused on broad trends and general findings, while the qualitative interviews provided more nuanced, specific examples of how the gap manifests in practice. For instance, the interviewees shared personal experiences of working with graduates who were knowledgeable about sustainability concepts but lacked the practical skills needed to implement them in real-world settings. This specific feedback offers valuable insights that were not as detailed in the SLR, thus enriching the overall understanding of the issue.

Addressing Gaps and Limitations in Previous Studies

This research makes a significant contribution by addressing the gaps identified in previous studies. Many existing studies have explored the importance of sustainability in maritime education but have often focused on theoretical aspects or broad curricular changes. By integrating qualitative data from industry professionals, lecturers, and graduates, this study provides a more comprehensive understanding of the real-world challenges faced in implementing green technologies in vocational training programs. Furthermore, the study highlights the specific areas where educational institutions are falling short in terms of practical training and the types of green technologies that need to be prioritized.

One limitation of previous research in this area has been the lack of direct input from industry professionals. While many studies have focused on the perspectives of educators and researchers, fewer have gathered insights from those actively working in

the maritime industry. This research bridges that gap by incorporating the perspectives of maritime entrepreneurs, officers, and managers, providing a more complete picture of the challenges and opportunities related to the green shipping transition.

Practical Implications of the Findings

The practical implications of these findings are far-reaching. The results suggest that maritime vocational programs must place a greater emphasis on practical, hands-on training with green technologies. This could involve the development of specialized training modules, workshops, or simulations that allow students to interact with the latest sustainable technologies used in the maritime industry. Additionally, there is a clear need for stronger collaboration between educational institutions and maritime companies to ensure that curricula are aligned with industry needs. This could take the form of industry advisory boards, internships, or joint research projects that allow students to gain real-world experience while still in training.

Another important practical implication is the need for more robust industry-driven certifications related to green shipping. Many interviewees noted that while some certifications exist, they are not universally recognized or widely offered in maritime vocational programs. Expanding the availability of such certifications would provide graduates with tangible proof of their expertise in green technologies, making them more competitive in the job market.

5. CONCLUSION

This research has provided valuable insights into the integration of green technologies in maritime vocational education, highlighting both progress and significant gaps. The findings underscore the growing recognition of sustainability within maritime training programs, yet the lack of hands-on, practical experience with green technologies remains a critical challenge. Although curricula are evolving to include sustainability concepts, the gap between theoretical knowledge and practical application continues to hinder the effective preparation of future maritime professionals for the green shipping transition. The study revealed that while there is alignment between industry needs and educational outcomes in terms of sustainability, the implementation of practical skills training in green technologies lags behind. This misalignment points to the need for stronger collaboration between educational institutions and the maritime industry to ensure that curricula stay up-to-date with technological advancements and industry

expectations. By addressing these gaps and enhancing the practical training aspect of maritime education, this research offers a roadmap for improving vocational programs and ensuring that maritime professionals are adequately equipped to handle the demands of the green shipping era. The findings also stress the importance of industry-driven certifications and real-world training opportunities to bridge the divide between theory and practice. Ultimately, this research contributes to the broader discussion on sustainability in maritime education and offers actionable recommendations for both educational institutions and the maritime industry.

LIMITATION

This study has opened several avenues for future research. One area that warrants further investigation is the development of standardized curricula for green technologies in maritime education. Given the rapid pace of technological change, it would be valuable to explore how educational institutions can quickly adapt their curricula to incorporate emerging green technologies. Additionally, further research could focus on the effectiveness of different teaching methods for green technologies, such as the use of virtual simulations, interactive labs, or collaborative projects with industry partners.

Another potential area for future research is the long-term impact of green technologies in maritime vocational education. It would be valuable to study how the integration of these technologies into training programs affects the employability and career progression of graduates, as well as the overall impact on the sustainability of the maritime industry.

This research has provided valuable insights into the integration of green technologies in maritime vocational education and the alignment between industry needs and educational outcomes. The findings reveal significant progress but also highlight critical gaps, particularly in terms of practical training and the need for closer collaboration between academia and industry. By addressing these gaps, educational institutions can play a pivotal role in preparing the next generation of maritime professionals to navigate the green shipping transition successfully. The study also offers important implications for policymakers, educators, and industry leaders, emphasizing the need for continued investment in sustainable training programs and greater alignment between education and industry needs.

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