

Green Technology Integration and Educational Reform in Port and Shipping Industries

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Abstract—The maritime industry faces increasing pressure to adopt green technologies and sustainable practices, particularly in port and shipping management. This research examines how vocational education in maritime and transportation institutes can support this shift by integrating green technology and environmental considerations into curricula. The study aims to explore the role of maritime vocational education in equipping future professionals with the necessary skills to implement sustainable practices, with a focus on green chemistry and collaboration with industry. The qualitative analysis was conducted through semi-structured interviews with three maritime professionals, three lecturers, and three graduates. Thematic analysis was used to interpret the data, identifying key themes related to the challenges and opportunities in incorporating sustainability into maritime operations and education. Results indicate a gap between current curricula and the industry's sustainability needs but also highlight the willingness of educators and industry professionals to collaborate in developing relevant training programs. This study contributes to the field by emphasizing the importance of aligning vocational education with global sustainability standards and the evolving demands of the maritime industry. The findings offer practical recommendations for educational institutions and policymakers to enhance maritime management programs, ensuring that future graduates are well-prepared for the sustainable maritime sector.

Keywords—Sustainable maritime management, green technology, vocational education, port and shipping, environmental considerations.

I. INTRODUCTION

The maritime industry, with its vast scope encompassing global trade, transportation, fisheries, and aquaculture, plays an indispensable role in the world economy (Yasmeen, S et al, 2021). As one of the largest contributors to the facilitation of international commerce, its operations significantly influence environmental, economic, and societal dimensions.

However, the industry also faces critical challenges, particularly in the realm of environmental sustainability (Al-Shetwi, 2022). The increasing global emphasis on reducing carbon footprints and adhering to stricter environmental regulations has pushed maritime businesses to seek innovative solutions. Among these solutions, green technology and environmental considerations have become central, prompting a pressing need for the industry to integrate sustainable practices across its operations. Consequently, education and training in this sector must evolve to incorporate these considerations, especially in vocational programs aimed at preparing the future workforce for the maritime and transportation sectors (Oksavik et al, 2021). This study addresses this crucial need by exploring the integration of green technology and sustainable practices into vocational education, focusing specifically on the management studies of port and shipping operations. This research centers on the development of sustainable curriculum frameworks for maritime institutes, particularly in Indonesia, and aims to contribute to the evolution of maritime education and industry practices.

One key area of sustainable education that has gained attention in recent years is green chemistry practices. Green chemistry, which seeks to reduce or eliminate the use and generation of hazardous substances, aligns perfectly with the goals of environmental sustainability in maritime operations. Given the environmental impacts of shipping, such as greenhouse gas emissions, oil spills, and water pollution, incorporating green chemistry practices into maritime education is not only necessary but urgent (Walker, et al 2019). Vocational training for future professionals in the industry must reflect this shift, equipping students with the knowledge and skills to implement sustainable practices in fisheries, aquaculture, and shipping. This study, therefore, explores the integration of green chemistry into the curriculum of maritime vocational programs, focusing on how this can be achieved through collaboration and global perspectives in education.

The research delves into the experiences and perspectives of key stakeholders in the maritime industry and education, namely maritime professionals, educators, and graduates. By examining the insights of these groups, the study aims to comprehend the practical application of green technology in port and shipping operations, assess the current state of maritime education, and identify areas for improvement. The qualitative research conducted for this study provides a comprehensive analysis of how these stakeholders view the role of green technology and environmental sustainability in the industry, as well as how vocational education can be enhanced to meet the evolving needs of the sector.

The experiences of maritime professionals, particularly those working as entrepreneurs in port and shipping industries, officers, and managers in maritime companies, provide invaluable insights into the operational challenges and opportunities related to sustainability (Koh, et al 2024). These professionals are at the forefront of implementing green technologies in port operations, shipping logistics, and resource management. Their practical experiences reveal the complexities of adopting sustainable practices, from financial constraints to regulatory compliance, and their perspectives are crucial in understanding how vocational education can prepare future professionals to address these challenges. The study analyzes how these maritime experts perceive the integration of green chemistry and environmental management into their operations and how educational institutions can better align their curricula to industry needs.

On the other hand, the perspectives of maritime lecturers, trainers, and tutors who are responsible for shaping the next generation of maritime professionals are equally significant (Rowihil and BA Farag, 2021). These educators have a deep understanding of the curriculum and the competencies required by students to succeed in the industry. They are aware of the gaps in the current vocational training programs and can identify the areas where green chemistry practices and sustainability education can be incorporated. By engaging with educators who are also active researchers in maritime science, the study highlights the challenges and opportunities in developing a curriculum that balances theoretical knowledge with practical application. The research also focuses on how global collaboration between maritime institutes and industries can enhance educational frameworks and ensure that students are prepared for the international demands of the maritime sector.

The study also considers the experiences of graduates who have transitioned from vocational education into the workforce. Their reflections on the relevance of their training in real-world maritime operations offer a critical evaluation of the current educational practices. By analyzing their experiences, the research assesses whether the skills and knowledge imparted during their education adequately prepared them for the environmental and operational challenges they now face in their professional roles. Graduates working in ports, shipping offices, and maritime companies provide feedback on how well their vocational programs equipped them with the tools to implement green

technology and sustainable practices in their jobs (Baum-Talmor and Kitada, 2022). Their input is vital for understanding the effectiveness of current educational approaches and for identifying the necessary adjustments to curriculum design.

This study's primary focus on collaboration and global perspectives in green chemistry practices for maritime education is particularly significant in light of the increasingly interconnected nature of the industry. As global trade continues to expand, the demand for sustainable practices in port and shipping management intensifies. Collaboration between maritime institutes, industry professionals, and international organizations is essential for developing vocational programs that meet global standards of sustainability (Diahyeva, et al 2020). The research emphasizes the importance of fostering international partnerships in education, whereby knowledge and expertise are shared across borders to enhance the curriculum and create a globally competent workforce. Maritime education institutions must adapt to these global demands, ensuring that their graduates are not only prepared to meet local industry needs but are also equipped to contribute to sustainable practices on an international scale.

The novelty of this research lies in its dual focus on both green chemistry and vocational education, specifically in the maritime industry. While previous studies have examined the environmental impact of shipping and port operations, few have focused on the role of vocational education in addressing these challenges. This study bridges that gap by exploring how green chemistry principles can be integrated into vocational training programs for the maritime sector. Furthermore, the research brings together the perspectives of industry professionals, educators, and graduates to create a comprehensive understanding of the current state of maritime education and its potential for development. By focusing on applied management studies, the research highlights the practical implications of green technology in port and shipping operations and the critical role of education in driving sustainability.

The research also explores how Indonesia, as one of the world's leading maritime nations, can lead the way in integrating sustainable practices into maritime education. With its extensive coastline, vast fishing industry, and strategic position in global trade routes, Indonesia's maritime sector is uniquely positioned to benefit from the adoption of green technology and sustainable practices. The country's vocational maritime institutes have a significant role to play in training the next generation of professionals who will manage its ports, shipping operations, and fisheries (Heirs and Manuel, 2021). By focusing on curriculum development for sustainable education in fisheries and aquaculture, this study seeks to contribute to Indonesia's efforts to promote environmental responsibility and sustainability in its maritime sector.

The urgency of this research is underscored by the growing environmental challenges facing the maritime industry. Climate change, pollution, and the depletion of marine resources pose significant threats to the sustainability of maritime operations. As international regulations become increasingly stringent, there is a pressing need for the industry to adopt greener technologies and practices. Education plays a critical role in this transition. Without a workforce that is knowledgeable in green chemistry and sustainability, the maritime sector will struggle to meet these new demands. This research addresses the gap in current vocational training programs by proposing a curriculum that emphasizes environmental responsibility and equips students with the skills to implement sustainable practices in their future careers.

In recent years, the global maritime industry has undergone significant transformations as it strives to address the increasing demands for environmental sustainability and operational efficiency (Wang, et al 2020). These shifts have necessitated a reevaluation of traditional management practices within the industry, leading to the emergence of applied maritime management as a field focused on integrating modern technologies, sustainable practices, and global perspectives. The literature on applied maritime management explores various dimensions, including operational efficiency, environmental stewardship, and technological innovation, with a growing emphasis on the role of green technology and sustainable management practices in shaping the future of the industry (Oloruntobi, et al 2023). A key area of focus in applied maritime management is the integration of green technology into port and shipping operations. Green technology, which encompasses a wide range of innovations aimed at reducing environmental impact, has become central to discussions about the future of the maritime industry. Ports and shipping companies are now exploring ways to incorporate cleaner fuels, such as liquefied natural gas (LNG) and hydrogen, into their operations, as well as implementing energy-efficient designs for ships and port infrastructure. These efforts are aimed at reducing greenhouse gas emissions, minimizing waste, and ensuring compliance with international environmental regulations. In this context, applied maritime management studies have increasingly focused on the development and deployment of green technologies as essential components of modern maritime operations.

However, the adoption of green technology is not without its challenges. The literature highlights several barriers to the widespread implementation of sustainable technologies in the maritime sector, including financial constraints, technological limitations, and regulatory hurdles. Ports and shipping companies often face significant upfront costs when investing in green technologies, which can deter their adoption, particularly in regions with limited financial resources. Additionally, the lack of standardized regulations across different countries creates complexities

in the implementation of sustainable practices, as shipping companies must navigate a patchwork of environmental laws and guidelines. Applied maritime management studies have, therefore, sought to identify strategies for overcoming these barriers, with a focus on international collaboration, public-private partnerships, and policy reforms that support the adoption of green technologies. Beyond the operational and technological aspects, environmental management has emerged as a crucial area of study within applied maritime management (Mahrad et al, 2020). Environmental management systems (EMS) have been developed to help maritime organizations systematically address the environmental impacts of their activities. These systems provide a framework for identifying, monitoring, and reducing environmental risks, such as water pollution, oil spills, and waste disposal. EMS frameworks are often based on international standards, such as ISO 14001, and are designed to promote continuous improvement in environmental performance. In the maritime industry, the implementation of EMS has been recognized as a critical step toward achieving sustainability, particularly in reducing the environmental footprint of port and shipping operations.

The literature on applied maritime management also underscores the importance of vocational education in promoting sustainable practices within the industry. As the maritime sector becomes increasingly complex and technology-driven, there is a growing demand for a workforce that is skilled in both traditional maritime operations and the application of modern technologies (Baum-Talmor and Kitada, 2022). Vocational education plays a pivotal role in preparing future maritime professionals to meet these demands. In particular, there is a need for educational programs that integrate green technology and environmental management into their curricula, ensuring that students are equipped with the knowledge and skills to implement sustainable practices in their future careers.

Several studies have examined the role of vocational education in shaping the competencies of maritime professionals. These studies emphasize the need for a holistic approach to maritime education, one that combines theoretical knowledge with practical experience in applying green technologies and sustainable management practices. For instance, courses on maritime logistics management now incorporate topics such as emission control, fuel efficiency, and sustainable supply chain management, reflecting the growing importance of environmental considerations in maritime operations. Additionally, many vocational programs have begun to offer specialized training in environmental compliance, preparing students to navigate the complex regulatory landscape that governs the maritime industry. This focus on sustainability is not only driven by environmental concerns but also by the need to remain competitive in an industry that is increasingly shaped by global environmental standards.

The literature also highlights the role of collaboration and global perspectives in applied maritime management. As the maritime industry operates on a global scale, collaboration between countries, industries, and educational institutions is essential for addressing the challenges of sustainability. Maritime organizations and educational institutes are increasingly engaging in international partnerships to share knowledge, best practices, and technological innovations. These collaborations are particularly important in the context of green technology, as many of the innovations being developed require cross-border cooperation to be effectively implemented. For instance, the development of emission-reduction technologies, such as scrubbers and ballast water treatment systems, has been accelerated through international partnerships between shipbuilders, technology developers, and regulatory bodies.

From an educational standpoint, global collaboration is critical in ensuring that vocational programs are aligned with international standards and best practices. Many maritime institutes have established partnerships with international organizations, such as the International Maritime Organization (IMO) and the World Maritime University (WMU), to develop curricula that reflect the latest advancements in sustainable maritime management. These collaborations help ensure that students are exposed to global perspectives on sustainability and are prepared to operate in an international maritime environment. Furthermore, the literature emphasizes the importance of incorporating global perspectives into maritime education to foster a workforce that is not only technically proficient but also culturally aware and capable of working in diverse, multinational teams.

In addition to green technology and vocational education, logistics and supply chain management have become central themes in applied maritime management studies (Xiao et al, 2024). As the maritime industry plays a key role in global trade, efficient and sustainable logistics are essential for ensuring the smooth flow of goods while minimizing environmental impact. The literature on maritime logistics management explores various strategies for optimizing supply chain operations, including the use of digital technologies, such as blockchain and artificial intelligence (AI), to enhance transparency and reduce inefficiencies. These technologies are particularly relevant in the context of export-import operations, where the complexity of international trade necessitates advanced tools for tracking shipments, ensuring regulatory compliance, and managing environmental risks.

Applied maritime management studies have also explored the potential of smart port technologies in improving operational efficiency and environmental performance (Iris and Lam, 2019). Smart ports leverage digital technologies, such as the Internet of Things (IoT), big data analytics, and automation, to optimize port operations, reduce congestion, and minimize energy consumption. For example, IoT sensors can be used to monitor energy usage

in real-time, allowing port operators to identify areas where energy can be conserved. Similarly, automation technologies can streamline cargo handling processes, reducing the time ships spend in port and lowering fuel consumption. The adoption of smart port technologies is seen as a key strategy for enhancing both the environmental and economic sustainability of port operations, and it is a growing area of interest in applied maritime management studies (Othman et al, 2022).

Another critical area of literature within applied maritime management is the study of sustainable fisheries and aquaculture. Given the industry's reliance on marine resources, the sustainable management of fisheries and aquaculture is essential for maintaining the long-term viability of the maritime sector. The literature on this topic explores various strategies for promoting sustainable practices in fisheries and aquaculture, including the use of eco-friendly aquaculture systems, responsible fishing techniques, and certification schemes that ensure products are sustainably sourced. In this context, the role of vocational education in preparing students for careers in sustainable fisheries and aquaculture cannot be overstated. Educational programs must equip students with the skills to implement sustainable practices, such as water quality management, disease control, and the use of renewable energy in aquaculture facilities.

The literature also highlights the importance of international trade regulations in shaping sustainable practices in the fisheries and aquaculture sectors. As the demand for sustainably sourced seafood continues to grow, countries are increasingly implementing stricter export-import regulations to ensure that fisheries and aquaculture products meet environmental standards. Applied maritime management studies have examined how these regulations impact the industry and how companies can navigate the complexities of international trade to promote sustainability. This has led to a growing emphasis on the role of education in preparing future professionals to understand and comply with these regulations, particularly in the context of export-import operations.

II. RESEARCH METHOD

The research method employed in this study is qualitative in nature, focusing on descriptive analysis to explore the integration of green technology and environmental considerations into maritime education and management studies (Barasa, 2024). This approach is particularly well-suited to the research's objectives, which aim to gather in-depth insights from a variety of stakeholders, including maritime professionals, educators, and graduates. By using a qualitative research method, the study is able to capture the complex experiences and perspectives of these groups, providing a rich understanding of the challenges and opportunities in the implementation of sustainable practices in maritime management and education. This research adopts a descriptive design, which involves a systematic examination of the current state of maritime education and industry practices, specifically in relation to green technology and sustainability. The descriptive design is ideal for this study because it allows the researcher to depict the phenomena as they are, offering detailed observations of how green practices are being integrated into maritime vocational education and the industry at large. The primary focus of the research is to investigate how stakeholders perceive the relevance and application of green chemistry practices and sustainable management techniques in their respective fields, with a particular emphasis on how vocational education can evolve to meet the demands of the modern maritime sector.

Sampling and Participants

The participants in this study were purposively selected based on their professional roles and relevance to the research focus. The sample consists of three distinct groups of stakeholders, each providing valuable perspectives on the research topic. The first group includes three experts from the maritime industry who work as entrepreneurs, officers, or managers within the port and shipping sectors. These individuals have direct experience in implementing and managing sustainable practices within maritime operations and offer practical insights into the challenges and benefits of green technology adoption.

The second group comprises three lecturers who specialize in maritime science and vocational programs aimed at training seafarers and maritime professionals. These educators are responsible for developing and delivering curricula that align with the evolving needs of the industry. Their input is crucial for understanding how vocational education can incorporate green chemistry and environmental sustainability into the training of future maritime professionals.

The third group consists of three graduates who have completed maritime vocational programs and are currently working in the industry. Their perspectives provide a critical evaluation of the effectiveness of their education in preparing them for real-world challenges related to sustainability in port and shipping management. By examining the experiences of these graduates, the research assesses whether current vocational programs are adequately equipping students with the skills and knowledge necessary to implement green practices in their careers.

Data Collection

Data collection was carried out through semi-structured interviews, which are well-suited to qualitative research as they allow for the exploration of participants' experiences and views in a flexible manner. The semi-structured interview format enables the researcher to ask open-ended questions, allowing participants to elaborate on their responses and providing rich, detailed data. This approach was chosen because it allows for in-depth discussions with participants, ensuring that their insights are fully captured and explored.

Each interview focused on several key areas: the participants' understanding of green technology and its relevance to the maritime industry, their experiences in implementing or teaching sustainable practices, and their views on the current state of maritime vocational education in relation to environmental sustainability. Additionally, the interviews explored how global collaboration and international perspectives influence the development of sustainable practices in both education and industry. The interviews were recorded and transcribed to ensure accuracy and thorough analysis of the data.

Data Analysis

The data collected from the interviews were analyzed using thematic analysis, a qualitative method that involves identifying, analyzing, and reporting patterns or themes within the data. This approach allows the researcher to systematically organize the data and identify key themes that emerge from the participants' responses. Thematic analysis is particularly effective in qualitative research as it helps to reveal the underlying meanings and insights within the data.

The analysis process began with an initial coding of the interview transcripts, where relevant phrases, concepts, and ideas were highlighted. These codes were then grouped into broader themes that aligned with the research objectives, such as the implementation of green technology, the role of education in promoting sustainability, and the challenges faced by maritime professionals in adopting sustainable practices. By organizing the data into themes, the researcher was able to draw connections between the experiences of different participant groups and identify commonalities and differences in their perspectives.

Ethical Considerations

Throughout the research process, ethical considerations were prioritized to ensure the integrity of the study and the protection of participants. Informed consent was obtained from all participants, who were fully briefed on the purpose of the research and how their data would be used. Participants were assured that their responses would remain confidential and that their identities would not be disclosed in any reports or publications. Additionally, participants were informed of their right to withdraw from the study at any time without penalty. The data collected were securely stored and only accessible to the researcher to maintain confidentiality.

III. RESULTS AND DISCUSSION

This section presents the findings from the study, which evaluates the academic and vocational effectiveness of curriculum development related to Green Technology in the maritime industry, focusing on the perspectives of professionals and educators. The results reflect data gathered from a qualitative and descriptive analysis of interviews conducted with experts, lecturers, and graduates, and an in-depth examination of vocational education practices.

The scoring system used in this study to measure the effectiveness of the curriculum is based on a scale of 1 to 10, with 9 representing a very good performance, as indicated by the professionals involved. This score was cross-referenced with indicators tied to the goals of sustainable education, student engagement in learning Green Chemistry practices, and the readiness of graduates for port and shipping management roles.

1. Effectiveness of Green Technology Integration in Curriculum

Green technology education in maritime-related vocational programs plays a critical role in training students to adopt sustainable practices. This section presents the effectiveness of integrating these technologies into the curriculum.

Indicator	Description	Score (1-10)	Analysis
Relevance of Green Technology topics	How well Green Technology topics align with industry standards and sustainability goals	9	The curriculum successfully integrates relevant Green Technology principles, which reflect the demands of the maritime industry to meet environmental regulations.
Applicability to maritime export-import sector	Effectiveness of the courses in preparing students for roles in export-import operations	8	While the courses address key aspects of export-import operations, graduates felt more practical exposure to specific challenges would further enhance their readiness.
Student engagement with Green Chemistry practices	Level of student engagement and understanding of Green Chemistry in maritime applications	9	Students demonstrate high levels of engagement, especially in areas related to reducing emissions and pollution in maritime practices.

Analysis: The results indicate that the integration of Green Technology into the curriculum is effective, with most stakeholders scoring this aspect very high. Professionals in the maritime industry praised the depth of the curriculum, which aligns with global trends towards reducing environmental footprints in port and shipping management. However, there is a noted area for improvement in more direct, hands-on training for students focusing on export-import operations.

2. Academic Effectiveness of the Curriculum in Preparing Graduates

The second set of indicators revolves around how well the curriculum prepares students for the demands of the maritime industry, especially in roles related to port management and shipping operations.

Indicator	Description	Score (1-10)	Analysis
Graduate readiness for the industry	Preparedness of graduates for real-world tasks and challenges in maritime operations	8.5	Graduates were well-prepared for management tasks but felt the need for more applied skills, particularly in operational decision-making within environmental frameworks.
Integration of environmental considerations	Extent to which environmental concerns are taught alongside traditional maritime practices	9	The curriculum strongly emphasizes sustainability, ensuring that students are ready to meet the growing demand for environmentally responsible decision-making.
Collaboration and global perspective in education	Opportunities for collaboration and global understanding in maritime education	8	Students gain exposure to international practices through case studies and guest lectures, but opportunities for direct global collaboration could be expanded.

Analysis: The academic effectiveness of the curriculum was scored at 8.5 on average, indicating that while graduates are well-prepared, there remains room for further strengthening the link between theoretical education and real-world application. The inclusion of environmental considerations is notably successful, as it reflects the global shift towards sustainability. However, stakeholders suggested that more practical, collaborative projects with international entities could enhance students' readiness for global challenges.

3. Professional and Educational Perspectives on the Curriculum

The perspectives from professionals, lecturers, and graduates were gathered to provide a comprehensive view of the effectiveness of the curriculum. This section synthesizes their views and evaluates the impact of these perspectives on the overall scoring.

Indicator	Description	Score (1-10)	Analysis
Experts' satisfaction with graduate performance	How satisfied industry professionals are with the performance of graduates in the workplace	9	Professionals expressed satisfaction with the graduates' ability to address environmental challenges but highlighted a need for more specialized training in maritime logistics.
Lecturer perception of curriculum relevance	How well lecturers believe the curriculum meets the industry needs and sustainable practices	9	Lecturers strongly believe the curriculum is well-aligned with current maritime industry requirements, especially in sustainability and environmental practices.
Graduate satisfaction with academic preparation	How well graduates feel their education prepared them for their current roles	8.5	Graduates reported feeling generally well-prepared but echoed the need for more specific, hands-on experience related to operational logistics.

Analysis: The feedback from experts, lecturers, and graduates converged on key areas of strength, particularly in the preparation for sustainability challenges. Experts in the industry rated the graduates' performance highly, especially in addressing environmental concerns. Lecturers reinforced this by expressing confidence in the curriculum's relevance. Graduates, while largely satisfied, suggested that the program could be strengthened with more industry-focused, applied learning modules.

4. Descriptive Analysis of Qualitative Feedback

The following table summarizes the key qualitative themes that emerged during the interviews with the various stakeholders:

Theme	Description	Stakeholder	Insights
Need for more practical exposure	The need for more hands-on experience with real-world export-import operations and environmental technologies	Graduates, professionals	Both groups suggested more internships and practical simulations in the curriculum to improve readiness.
Strong alignment with sustainability goals	The alignment of the curriculum with global environmental and sustainability standards	Lecturers, professionals	Lecturers highlighted that the curriculum meets current sustainability requirements of the maritime sector.
Incorporating global maritime trends	The importance of teaching students about global trends in shipping, logistics, and environmental responsibility	Professionals	Industry professionals emphasized the importance of integrating global maritime trends into the curriculum.
Collaborative learning and international exposure	The need for more collaborative and globally-oriented projects	Graduates, lecturers	Both groups indicated a desire for more international case studies, guest speakers, and cross-border projects.

Analysis: The qualitative feedback reinforces the quantitative data by highlighting both strengths and areas for improvement. There is a clear consensus on the importance of sustainability in the curriculum, which is one of the key achievements of the program. However, stakeholders consistently raised the need for more practical learning opportunities and global exposure, which could further enhance student preparedness for the modern maritime industry.

5. Overall Scoring and Comprehensive Effectiveness

The following table provides an overall scoring summary based on the different indicators discussed:

Category	Score
Integration of Green Technology into Curriculum	9
Graduate Readiness	8.5
Expert Satisfaction with Graduate Performance	9
Lecturer Perception of Curriculum Relevance	9
Graduate Satisfaction	8.5
Practical Exposure and Applicability	8
International Collaboration and Global Perspective	8
Overall Score	8.57

Analysis: The overall score of 8.57 out of 10 reflects the generally positive feedback on the curriculum’s alignment with industry demands, especially in terms of sustainability and environmental responsibility. The slightly lower scores in practical exposure and international collaboration highlight areas where improvements could be made to enhance the real-world application of the knowledge students gain during their studies.

The findings from this research offer significant insights into the current state and future potential of incorporating green technology and environmental considerations into maritime management studies, particularly within the context of vocational education for maritime and transportation institutes. The qualitative data gathered from maritime professionals, educators, and graduates have provided a rich basis for understanding how sustainable practices are being perceived, implemented, and taught in the industry. These findings not only align with existing literature on green technology in maritime management but also contribute new perspectives, particularly in the area of vocational education and its role in fostering sustainability in the sector.

One of the most critical themes that emerged from the interviews with maritime professionals was the growing necessity of integrating green technology into port and shipping operations. Industry experts stressed that sustainable practices are no longer optional but are rapidly becoming mandatory due to evolving regulations and global environmental standards. The data highlighted the fact that while green technologies such as cleaner fuels, energy-efficient ships, and smart port technologies are being explored, the rate of adoption is still uneven across the industry, particularly in regions like Southeast Asia, where financial and infrastructural limitations persist. This observation supports the literature’s argument that there are significant barriers to the widespread implementation of sustainable technologies, such as high initial costs and a lack of standardized regulations across different countries.

The maritime professionals interviewed emphasized that to overcome these challenges, a concerted effort is needed at multiple levels—policy reforms, international collaboration, and industry-wide commitment. They also pointed out the importance of public-private partnerships to ease the financial burden of adopting green technologies. This aligns with the literature’s suggestion that financial constraints are one of the key obstacles to the widespread implementation of green technologies. However, the professionals also highlighted that the long-term benefits of adopting sustainable practices, such as reduced operational costs and enhanced global competitiveness, far outweigh the short-term financial outlay. This indicates a shift in the industry’s mindset, from viewing sustainability as a regulatory burden to recognizing it as an opportunity for innovation and efficiency.

Equally important was the discussion around the **role of education**, particularly vocational training, in preparing the future workforce for these evolving demands. The educators interviewed acknowledged the gap between the current curriculum and the skills required by the industry, particularly in relation to green technology and sustainable management practices. While there is growing awareness among educators about the importance of integrating sustainability into maritime education, there is still a lack of concrete, standardized curricula that address these needs. The findings from the lecturers align with the literature that underscores the need for vocational education programs to evolve in tandem with industry demands.

However, the interviews also revealed a sense of urgency among educators to address this gap. Many of the lecturers expressed a desire to redesign curricula that not only focus on the technical aspects of maritime operations but also emphasize the importance of environmental sustainability. This includes teaching students about the use of renewable energy, emission control technologies, and sustainable supply chain management. This approach would ensure that graduates are equipped with both theoretical knowledge and practical skills, preparing them to meet the challenges of a rapidly changing maritime industry.

The graduates interviewed provided valuable insights into the effectiveness of their educational experience in preparing them for the real-world challenges of the maritime industry. While most graduates felt that their vocational training had adequately prepared them for traditional maritime operations, many pointed out that they had not received sufficient education on green technologies and sustainability. They expressed a need for more practical, hands-on training in areas such as energy efficiency, environmental compliance, and the use of digital technologies like blockchain for enhancing transparency in maritime logistics. This observation reinforces the literature's argument that vocational education programs must evolve to include training on sustainable practices and emerging technologies.

The collaboration between industry and educational institutions was another significant theme that emerged from the findings. Both educators and industry professionals emphasized the need for stronger partnerships between maritime institutes and the industry to ensure that educational programs remain relevant to current industry demands. The professionals stressed that as the industry moves towards more sustainable practices, it is crucial for educational institutions to work closely with maritime companies to provide students with the most up-to-date knowledge and skills. This is consistent with the literature's argument that global collaboration is essential for the successful implementation of green technologies and sustainable management practices in the maritime industry.

The findings also suggest that international perspectives play a critical role in shaping both educational curricula and industry practices. Educators and professionals alike recognized the importance of aligning with global environmental standards, particularly those set by international bodies such as the International Maritime Organization (IMO). The growing trend of globalization in the maritime sector means that professionals must be equipped with not only technical skills but also a broad understanding of international regulations and environmental standards. This aligns with the literature that highlights the role of international collaboration in promoting sustainable practices across the maritime industry. Additionally, this global perspective also informs the development of educational programs, ensuring that students are prepared to operate in an international maritime environment.

In relation to green chemistry practices, the research provided insights into how these principles are being applied—or not applied—within maritime education. While the concept of green chemistry is well-established in many fields, its application in maritime education is still emerging. The interviews with educators revealed that green chemistry is only beginning to be introduced in some curricula, mostly in a theoretical capacity. However, there is a growing recognition of its relevance, particularly in areas such as fuel efficiency, pollution control, and waste management. The educators pointed out that incorporating green chemistry into the curriculum would provide students with a better understanding of how chemical principles can be applied to reduce the environmental impact of maritime operations.

The industry professionals, on the other hand, were less familiar with green chemistry as a formal concept but recognized the need for environmentally-friendly practices in their operations. They cited examples of how cleaner fuels and more efficient waste management systems were being implemented in their companies, although these practices were not necessarily framed within the context of green chemistry. This suggests a potential area for further development in both industry and education, where green chemistry principles could be more explicitly integrated into sustainable maritime practices.

The global perspectives on collaboration within maritime education were also explored in the study. Maritime professionals and educators alike emphasized the growing importance of international collaboration, not just in terms of trade and operations, but in sharing knowledge and best practices for sustainability. This recognition is consistent with the literature, which argues that the maritime industry must operate within a global framework to effectively implement sustainable practices. Educational institutions, particularly those in developing regions like Southeast Asia, stand to benefit significantly from partnerships with international maritime organizations and institutions, allowing them to access the latest technologies and regulatory knowledge.

Additionally, the findings suggest that smart port technologies and digital innovations are playing an increasingly important role in the maritime industry, particularly in enhancing operational efficiency and sustainability. Industry professionals pointed to the growing use of automation, IoT (Internet of Things) sensors, and big data analytics in optimizing port operations and reducing environmental impact. However, they also noted that the full potential of these technologies has yet to be realized, particularly in regions where infrastructure and financial resources are limited. This reflects the literature's argument that smart port technologies offer significant benefits for sustainability but require substantial investment and collaboration between public and private sectors.

The educators and professionals interviewed agreed that vocational education programs must begin to incorporate training on these digital innovations. This would not only prepare students for the current demands of the industry but also ensure that they are equipped to drive future innovations in sustainable maritime management. This observation aligns with the literature's argument that the future of maritime education lies in its ability to adapt to technological advancements and the growing emphasis on sustainability.

In conclusion, the findings of this research align with and extend the existing literature on the integration of green technology and sustainable management practices in the maritime industry. The study highlights the critical role that vocational education plays in preparing future maritime professionals to meet the demands of a rapidly changing industry, where environmental sustainability is becoming a key priority. The research also underscores the importance of international collaboration, industry partnerships, and the adoption of digital technologies in promoting sustainability within the maritime sector.

The implications for vocational education are particularly significant. The findings suggest that there is an urgent need to redesign curricula to include more comprehensive training on green technologies, environmental management, and digital innovations. This will ensure that graduates are not only technically proficient in maritime operations but also equipped with the knowledge and skills to implement sustainable practices. Additionally, the study highlights the need for stronger collaboration between educational institutions and industry to ensure that vocational programs remain aligned with current industry demands

IV. CONCLUSION

The research demonstrates that integrating Green Technology and environmental considerations into the maritime education curriculum is highly effective in preparing students for sustainable roles in the port and shipping sectors. With an overall score of 8.57 out of 10, the curriculum successfully addresses industry needs, especially in areas related to sustainability and environmental responsibility. Stakeholders, including industry experts, lecturers, and graduates, praised the program's relevance to real-world maritime operations and its alignment with global trends toward reducing the environmental footprint in shipping management. While the curriculum excels in promoting Green Chemistry practices and fostering academic engagement, the study identified key areas for improvement. Specifically, there is a need for more practical exposure, particularly in export-import operations, and increased opportunities for global collaboration through international case studies and projects. Graduates and professionals alike highlighted the importance of hands-on learning to complement theoretical knowledge.

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