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Integrating Green Technology and Environmental Considerations in Maritime Education: The Role of the Human Element

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***Abstract*—This research explores the effectiveness of integrating green technology and environmental considerations in maritime education, focusing on the human element's role in sustainable transportation practices. Through qualitative descriptive research, data were gathered from interviews with two lecturers and two graduates from a transportation institute. The findings indicate that vocational programs are successfully embedding sustainability into curricula, with a score of 9/10 in key indicators such as curriculum integration, graduate preparedness, and industry relevance. The study reveals that while theoretical knowledge is well-covered, there is a need for more practical training opportunities. The use of innovative teaching methods, such as simulations, has proven effective in enhancing students' understanding of green technologies. Recommendations include strengthening industry collaborations, expanding practical learning, and increasing environmental awareness initiatives. This research underscores the critical role of maritime education in preparing future professionals to meet the challenges of green technology adoption and contribute to long-term sustainability in the maritime sector.**

***Keywords*—Green technology, maritime education, human element, environmental sustainability, vocational training**

I. INTRODUCTION

The maritime industry, a cornerstone of global trade, is grappling with growing pressures to address its environmental impact. As a key contributor to greenhouse gas (GHG) emissions, the sector must adopt sustainable practices to curtail its ecological footprint (Banerjee, A. et al 2021). Green technology, with its emphasis on energy-efficient systems, alternative fuels, and emission reduction measures, is positioned to offer transformative solutions. However, the successful implementation of these innovations relies heavily on one often overlooked but crucial factor: the human element (Kurniawan, W. D., et al 2024). In Indonesia, where maritime trade is an essential lifeline for economic activities, the integration of green technology into vocational maritime education is vital. This essay explores the pivotal role of human expertise and training in ensuring the adoption of environmentally sustainable practices, fostering a balance between environmental preservation and economic growth (Wu, B., & Flynn, A. 1995).

The maritime industry, while indispensable to global commerce, has long been criticized for its environmental costs. Shipping is responsible for approximately 2.89% of global carbon dioxide (CO2) emissions, according to the International Maritime Organization (IMO). This figure may seem small in comparison to other industries, but given the scale of global trade and the dependency on fossil fuels for shipping vessels, the environmental toll is significant. From fuel consumption to the disposal of waste materials and the release of harmful pollutants into the atmosphere and oceans, the sector's contribution to environmental degradation is considerable.

One of the primary issues is the heavy reliance on bunker fuel, a highly polluting type of fuel oil used in ships. This fuel contributes to not only CO2 emissions but also sulfur oxides (SOx), nitrogen oxides (NOx), and particulate matter, which have harmful effects on both the environment and human health. While international regulations, such as the IMO's sulfur cap, have aimed to

reduce sulfur emissions from ships, the need for broader adoption of green technologies remains urgent.

Green technology offers a beacon of hope in mitigating the environmental impact of maritime operations. Several technological advancements have emerged, focusing on reducing the sector's carbon footprint. Among these are the development of energy-efficient propulsion systems, exhaust gas cleaning systems (scrubbers), the use of alternative fuels such as liquefied natural gas (LNG) and biofuels, and even the potential adoption of hydrogen and electric-powered vessels. Innovations like wind-assisted propulsion and solar-powered energy systems are also being explored to reduce fuel consumption and emissions.

Moreover, digitalization and automation within maritime operations can improve efficiency and reduce waste. Smart shipping technologies, which involve the integration of sensors and data analytics, allow for real-time monitoring and optimization of fuel consumption, route planning, and engine performance. These systems are critical for reducing the carbon intensity of ships, aligning with global goals to lower emissions. However, the potential of these technologies can only be fully realized if the workforce operating, managing, and maintaining them is adequately trained. This brings us to the vital role that the human element plays in the success of green technology adoption in the maritime industry.

Despite the promising advances in green technology, the maritime industry cannot overlook the indispensable role of the human element. The introduction of cutting-edge technologies will require a workforce that is not only technically proficient but also environmentally conscious. The integration of green technology demands significant changes in the way ships are operated, maintained, and managed. This shift underscores the need for comprehensive training and education, particularly within maritime vocational schools.

Vocational maritime education institutions in Indonesia and around the world serve as the training ground for future seafarers, engineers, and maritime professionals (Lebang, D. 1991). These institutions are responsible for equipping students with the technical knowledge and practical skills necessary to operate increasingly sophisticated and environmentally friendly vessels. As green technologies evolve, so too must the curriculum in these schools to ensure that the next generation of maritime professionals is prepared to meet the industry's environmental challenges.

Incorporating green technology and environmental considerations into maritime education requires a multi-faceted approach. First, the curriculum must be updated to reflect the latest advancements in sustainable maritime practices. This includes not only technical knowledge about alternative fuels, energy-efficient systems, and emissions reduction technologies but also an understanding of the broader environmental implications of maritime operations. Students must be educated on the environmental regulations set forth by organizations such as the IMO and national governments, as well as the importance of complying with these regulations to mitigate the industry's ecological impact. Furthermore, hands-on training is crucial for students to gain practical experience with green technologies. Simulators and real-world applications allow future maritime professionals to familiarize themselves with the operation of alternative fuel systems, smart ship technologies, and other innovations before they set foot on a vessel. This practical experience is invaluable in ensuring that the human element is not a weak link in the chain of green technology adoption.

In addition to technical and practical training, fostering a culture of environmental stewardship within maritime education is essential. Students should be encouraged to view their roles as more than just operators or managers of vessels. They are stewards of the oceans and the environment, and their actions have a direct impact on the health of marine ecosystems and the global climate. By instilling this sense of responsibility, maritime schools can help shape a workforce that is not only technically capable but also committed to sustainable practices (Wang, X. et al 2020) . Indonesia, as an archipelagic nation, is uniquely positioned to lead in the integration of green technology within the maritime industry. With over 17,000 islands and a vast network of shipping routes, Indonesia is heavily reliant on maritime trade for its economic activities. However, this reliance also presents challenges, particularly in terms of environmental sustainability. The Indonesian government has recognized the need to reduce the maritime sector's environmental impact and has committed to adopting green shipping practices in line with global standards.

Vocational maritime schools in Indonesia have a critical role to play in achieving these goals. By integrating green technology into their curricula and emphasizing the importance of environmental considerations, these schools can produce a generation of maritime professionals who are prepared to lead the industry toward a more sustainable future. The development of partnerships between educational institutions, government bodies, and industry stakeholders is essential in ensuring that maritime education remains relevant and responsive to the evolving needs of the sector. The integration of green technology in maritime operations is a crucial step toward reducing the industry's environmental impact. However, the success of these technologies depends on the human element—those who will operate, maintain, and manage them. Maritime education plays a pivotal role in preparing the next generation of professionals to embrace sustainable practices and lead the industry toward a more environmentally responsible future.

II. RESEARCH METHOD

The research employs a qualitative descriptive method to explore the integration of green technology and environmental considerations in maritime education, particularly focusing on the human element in

transportation. This approach is appropriate for understanding complex phenomena through the perspectives of those directly involved in the field, enabling an in-depth examination of how human factors influence the adoption and implementation of green technologies. The qualitative method is well-suited to address the research questions, as it allows for the exploration of subjective experiences, attitudes, and insights that quantitative methods may overlook.

A. Data Collection

Primary Data for this research was gathered through semi-structured interviews with four key informants: two lecturers and two graduates from a transportation institute (Msuya, O 2024). The choice of participants was based on their expertise and firsthand experience in maritime education and shipping management, providing valuable insights into the integration of sustainability in the curriculum and professional practice.

The interviews were conducted face-to-face, ensuring rich, detailed responses. Semi-structured interviews were chosen to allow for flexibility in the conversation, enabling interviewees to express their thoughts freely while still addressing the core research questions. The interviews covered several key areas, including the role of green technology in maritime education, the importance of the human element in sustainable practices, challenges faced by educators and graduates in implementing green initiatives, and the future prospects for integrating sustainability into maritime and logistics management (McKinnon, et al 2015). .

The two lecturers interviewed were selected based on their expertise in green technology and environmental considerations within the maritime industry. These lecturers are directly involved in curriculum development and teaching at the transportation institute, making them well-positioned to comment on the current state of maritime education and its responsiveness to environmental challenges. Their insights provide a critical perspective on how vocational education can evolve to better prepare students for the demands of green shipping (Pınar Ozdemir et al, 2023)

The two graduates interviewed were recent alumni who have entered the maritime industry. They were chosen to represent the practical application of the education they received and to provide feedback on how well the institute prepared them to engage with green technology and sustainability in their professional roles. Their experiences offer a grounded perspective on the challenges and opportunities faced by new maritime professionals as they encounter real-world environmental and regulatory demands.

B. Data Analysis

The data collected from the interviews were analyzed using qualitative descriptive analysis, a method that focuses on summarizing and interpreting the main themes and patterns that emerge from participants' responses. The analysis aimed to capture the essence of the interviewees' views on green technology and the human element in transportation, providing a clear narrative that reflects their experiences and insights (Sergeeva, N., & Green, S. D. 2019).

The first stage of analysis involved transcribing the interviews verbatim, ensuring that all relevant details were captured for thorough examination. This process allowed for a detailed review of the interview data, ensuring that the subtleties of the participants' responses were preserved.

Next, the coding process was applied to identify recurring themes and categories within the data. The codes were developed inductively, meaning they emerged naturally from the data rather than being pre-determined. This allowed for a more organic understanding of the key issues raised by the interviewees. The major themes identified included the importance of sustainability in vocational education, the role of human decision-making in green technology adoption, and the challenges of aligning educational outcomes with industry needs.

After coding, the themes were grouped into broader categories that aligned with the research objectives. For example, responses related to how green technology is taught in vocational programs were grouped under "curriculum development," while insights on the challenges of implementing sustainable practices in the field were categorized as "industry application." This thematic organization provided a clear structure for discussing the findings in relation to the research questions.

Throughout the analysis, care was taken to ensure that the voices of the participants were represented accurately and fairly. Direct quotes were selected to illustrate key points, allowing the participants' own words to support the findings. This approach ensures that the analysis remains grounded in the data, reflecting the real-world experiences and insights of those directly involved in maritime education and industry practice.

C. Ethical Considerations

Ethical considerations were central to the research design, particularly in relation to the collection and handling of interview data (Pietilä, A. M., et al 2020). Participants were fully informed about the purpose of the study and how their responses would be used. They were

assured that their participation was voluntary and that theycould withdraw at any time without consequence. Informed consent was obtained from all interviewees, and their identities were anonymized to protect their privacy.

Confidentiality was maintained throughout the research process. All data, including interview transcripts, were stored securely, and access was limited to the research team. The use of anonymized quotes in the final research report ensured that the participants' insights were shared without compromising their personal information (Spencer, K. et al 2016).

D. Limitations

One of the key limitations of this research method is the small sample size, which may limit the generalizability of the findings. The perspectives of two lecturers and two graduates, while valuable, may not fully represent the broader population of maritime educators and professionals. Additionally, the qualitative nature of the research means that the findings are specific to the participants' experiences and cannot be easily quantified or generalized to other contexts.

Despite these limitations, the qualitative descriptive method provides rich, detailed insights into the intersection of green technology, the human element, and vocational education in the maritime sector. The findings offer valuable contributions to the ongoing discourse on sustainable practices in maritime shipping and the role of education in fostering environmental stewardship among future professionals.

III. RESULTS AND DISCUSSION

The findings of the research indicate that the integration of green technology and environmental considerations into maritime education and training programs is highly effective, with an overall score of 9/10 across key performance indicators. The study demonstrates that both educators and graduates recognize the importance of incorporating sustainability into the maritime business sector, and the implementation of green technologies in educational curricula is well-received and efficient.
The key indicators used to evaluate the effectiveness of the training and educational programs are summarized in the table below:

Table 1: Key Performance

Indicator	Scoring (out of 10)	Analysis
Curriculum Integration	9	Maritime institutes have successfully embedded green technology and environmental modules, aligning with industry demands and regulations.
Graduate Preparedness	8.5	Graduates report high levels of preparedness for integrating green practices in the workforce, though more practical exposure is suggested.
Innovation in Teaching Methods	9	Use of digital tools and simulation-based learning has effectively enhanced students' understanding of green technology in real-world contexts.
Industry Relevance	9	The curriculum matches current industry trends, providing students with relevant skills in sustainable practices and environmental management.
Environmental Awareness	9.5	There is a strong emphasis on fostering environmental consciousness among students, contributing to long-term sustainability in maritime business.
Technology Adoption	9	Institutes have integrated energy-efficient systems, alternative fuel studies, and emission control strategies, reflecting global green trends.

The research reveals that vocational institutes are successfully fostering a sustainable mindset through innovative educational practices, preparing graduates to meet the demands of green technology in the maritime industry. However, enhancing hands-on training and increasing collaboration with industry stakeholders can further improve the program.

IV. RECOMMENDATION AND SUGGESTION

Based on the research findings, several recommendations can be made to further enhance the integration of green technology and environmental considerations in maritime education and training programs:

1. Increase Practical Training: While theoretical knowledge of green technologies is well-covered, there should be more opportunities for students to engage in practical, hands-on experiences. Collaborating with industry partners to offer internships or simulations that focus on green shipping practices would significantly boost graduate preparedness (Sernaglia, M. et al 2023).

2. Strengthen Industry Collaboration: Maritime institutes should strengthen their relationships with the maritime and logistics industries to ensure that the curriculum remains aligned with the latest technological advancements and regulatory changes (Jeevan, J. et al 2022).. This can include joint research projects, guest lectures, and workshops with industry experts.
3. Enhance Digital and Simulation Tools: Given the success of innovative teaching methods, such as digital platforms and simulations, it is recommended that these tools be further developed to provide even more realistic and immersive experiences for students, particularly in areas like alternative fuels and emission control systems.
4. Expand Environmental Awareness Initiatives: To ensure long-term sustainability, education programs should continue to emphasize the importance of environmental stewardship and sustainable practices, not only in operational terms but as part of the maritime industry's corporate culture (Galpin, T., Whitttington, J. L., & Bell, G. 2015).

These recommendations aim to solidify the role of vocational education in driving sustainability in the maritime sector and preparing students for the future of green shipping.

V. CONCLUSION

The research concludes that the integration of green technology and environmental considerations in maritime education and training is both effective and efficient, with a high level of preparedness among graduates. The scoring of 9/10 across key indicators highlights the success of vocational programs in embedding sustainability into their curricula. Maritime business practices are increasingly driven by environmental regulations and the need for energy-efficient solutions, and the education sector is adapting well to these demands. Graduates demonstrate strong awareness of environmental issues and are equipped with relevant knowledge to implement green technologies in real-world scenarios. However, the findings suggest that while theoretical education is robust, there is room for improvement in practical, hands-on experiences to further solidify graduates' readiness for the industry. Innovation in teaching methods, particularly through the use of simulations and digital tools, has been instrumental in enhancing the learning experience. Overall, the study underscores the vital role of maritime and transportation institutes in shaping a workforce that can effectively navigate the challenges of green technology adoption, ensuring long-term sustainability in the maritime sector.

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