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# ENGINEERING TECHNOLOGY AND EDUCATION IN MARITIME STUDIES: A QUALITATIVE EXAMINATION

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## Abstract

This study examines the integration of emerging technologies and sustainable practices within maritime engineering education in Indonesia. Focusing on the alignment of vocational training with advancements in automation, green technology, and operational efficiency, the research explores how maritime professionals and educators perceive and implement these innovations. Through qualitative analysis, critical areas emerge where maritime education must adapt to meet industry demands, particularly in sustainability, technological innovation, and practical skill development. Findings emphasize the importance of fostering strong partnerships between industry stakeholders and educational institutions, which are essential for enhancing the relevance and effectiveness of maritime engineering programs. This research contributes valuable insights toward improving vocational training frameworks, ensuring that graduates are well-prepared to navigate the complex, evolving landscape of the maritime sector.

Keywords: Emerging technologies, Industry-academia collaboration, Maritime engineering, Sustainable practices, Vocational education.

## 1. Introduction

The maritime industry plays a vital role in global trade and transportation, yet it faces increasing challenges and opportunities from rapid technological advancements and a global shift toward sustainability [1, 2]. As technologies like Artificial Intelligence (AI), automation, and advanced propulsion systems reshape maritime operations, the demand for new competencies among maritime professionals has grown [3, 4].

This shift underscores the need for innovative approaches to maritime education, especially in vocational programs where students are trained to operate complex engineering systems while adopting sustainable practices. For Indonesia, a country with an extensive reliance on maritime transportation due to its archipelagic geography, advancing education in marine engineering technology is both economically and environmentally crucial. Emerging technologies, such as AI-driven systems, automation in engine control, and data-driven decision-making tools, are transforming maritime operations, necessitating rapid adaptation in educational programs to prepare students for an increasingly complex industry.

This research investigates how engineering technology and education in Indonesia's maritime sector are adapting to these trends. Engaging with industry experts and educators, the study identifies both challenges and opportunities in integrating new technologies and sustainability into maritime education. Using qualitative methods, including interviews with maritime professionals and lecturers, the research explores how these advancements are being applied in vocational settings and addresses the gap between technological innovation and current educational practices.

Many vocational institutions struggle to keep pace with the rapid evolution of technology, risking a workforce unprepared for the modern demands of maritime operations [5, 6]. Moreover, as the industry faces pressure to adopt sustainable engineering practices, developing a workforce that is both technologically skilled and environmentally conscious is essential.

Ultimately, this study aims to contribute to the development of more effective educational strategies that align with industry requirements. By focusing on technological advancement and sustainability, it provides insights into preparing future maritime professionals for the challenges of the 21st century, offering a comprehensive view of how industry-driven innovations can reshape maritime engineering education through industry-academia collaboration.

## 2. Methods

This study employs a qualitative research design to explore the perspectives of industry experts and educators on advancing maritime engineering education through emerging technologies and sustainable practices. Due to the complexity and nuanced nature of this topic, a qualitative approach was deemed the most suitable, allowing for an in-depth understanding of maritime engineering, technology, and education dynamics [7, 8].

Data collection centered on semi-structured, in-depth interviews with four maritime professionals and four marine engineering lecturers, chosen for their extensive expertise in maritime operations, vocational education, and industry

technology. The professionals, each with experience in port and shipping operations, provided valuable insights into the practical challenges and opportunities associated with implementing emerging technologies. The lecturers, specialists in marine engineering and vocational training, discussed curriculum integration, skills development, and the inclusion of new technologies. This participant group allowed for a comprehensive view that captures both the industry's needs and the educational gaps [9, 10].

Interviews were conducted using a semi-structured format to facilitate open discussion while ensuring consistency across key topics. Each interview was recorded and transcribed for analysis, allowing for accurate data capture. Data analysis followed a thematic approach, where transcripts were coded and responses grouped into key themes, including technological integration, sustainability, vocational training, and industry alignment. This iterative thematic analysis highlighted shared challenges and needs, forming the basis for actionable recommendations to enhance vocational training programs in maritime education [11, 12].

## 3. Results

The results of this study, grounded in the qualitative perspectives of maritime experts, lecturers, and professionals, offer a deep understanding of how emerging technologies in maritime engineering and education contribute to enhancing efficiency, sustainability, and technological adoption in Indonesia's maritime vocational education sector.

The study focused on evaluating the effectiveness and efficiency of engineering practices within maritime sectors, particularly in marine engineering studies, by examining the perspectives of participants across multiple dimensions, including the integration of sustainable engineering practices, the adequacy of vocational training, the alignment of educational outcomes with industry needs, and the overall innovation landscape in maritime transportation.

### 3.1. Indicator 1: Effectiveness of sustainable engineering practices

One of the key findings of this research was the increasing effectiveness of sustainable engineering practices in maritime industries, as described by both professionals and educators. The analysis revealed that participants generally viewed the adoption of green technologies and eco-friendly materials as not only necessary but also as a growing trend in the industry. Entrepreneurial professionals in the maritime sector, particularly those involved in port and shipping operations, noted that investments in sustainable technologies, such as energy-efficient engines and waste-reduction systems, have led to measurable improvements in operational efficiency.

From the Table 1, it is clear that while industry professionals have started to implement these practices more broadly, the academic side lags slightly, with some concepts not yet fully integrated into vocational training programs. The efficiency score represents the overall effectiveness in real-world applications, showing that energy-efficient engines have had the most substantial impact, while circular economy principles, though acknowledged, require more practical adoption.

**Table 1. Sustainable engineering practices effectiveness.**

| Indicator | Industry Feedback (Professionals) | Academic Feedback (Lecturers) | Efficiency Score (%) |
|---|---|---|---|
| **Green Technologies Adoption** | High implementation in ports and shipping | Gradual inclusion in curriculum | 80% |
| **Circular Economy Implementation** | Limited adoption but growing | Concept taught, not practised | 60% |
| **Eco-friendly Materials** | Significant impact on cost reduction | Limited student exposure | 75% |
| **Energy-efficient Engines** | Critical to reducing emissions | Core topic in engineering courses | 85% |

## 3.2. Indicator 2: Vocational training and educational adequacy

The qualitative data obtained from interviews with lecturers indicated that while vocational training in marine engineering covers core engineering principles effectively, there is room for improvement in incorporating newer technologies into the curriculum. Most lecturers acknowledged that while students are being equipped with foundational knowledge, the dynamic nature of maritime technology requires continuous updating of educational materials.

The lecturers' feedback highlights that while the core fundamentals are taught well, the swift pace of technological advancement has left gaps in education that need to be bridged (Table 2). Graduates, particularly those already working in maritime industries, noted that they were not fully prepared for the latest technological requirements, suggesting that vocational programs must be continuously updated to stay relevant.

**Table 2. Vocational training adequacy.**

| Indicator | Lecturer Feedback | Graduate Satisfaction (from interviews) | Scoring (out of 10) |
|---|---|---|---|
| **Coverage of Core Marine Engineering** | Well-covered in existing curricula | Satisfactory (practical applications) | 8 |
| **Inclusion of Emerging Technologies** | Limited and dependent on institution | Graduates feel inadequately prepared for current tech | 5 |
| **Practical Training Opportunities** | Strong partnerships with industries | Generally positive experiences | 9 |
| **Alignment with Industry Demands** | Requires closer alignment | Needs improvement | 6 |

## 3.3. Indicator 3: Alignment of educational outcomes with industry needs

A critical area of focus was the extent to which educational outcomes align with the actual needs of the maritime industry. According to the professionals interviewed, there remains a gap between what is taught in maritime vocational schools and the skills required in the industry. While students are provided with solid technical knowledge, industry professionals noted that soft skills such as problem-solving, adaptability, and familiarity with new technologies are often lacking.

Table 3 illustrates a noticeable gap in technological familiarity and problem-solving skills, both of which are critical for the evolving maritime sector. Professionals in the industry indicated a significant need for educational reforms

that incorporate these competencies, suggesting that greater collaboration between industry and academia could help close this gap.

**Table 3. Industry alignment.**

| Indicator | Professional Feedback (Industry Needs) | Lecturer Feedback (Educational Gaps) | Alignment Score (%) |
|---|---|---|---|
| **Technical Skills** | High demand, well-covered in education | Needs more focus on new tech | 75% |
| **Soft Skills (Problem-solving)** | Not adequately addressed | Not a priority in curriculum | 60% |
| **Technological Familiarity** | Lagging behind industry expectations | Gaps in technology integration | 50% |
| **Sustainability Awareness** | Increasingly important | Being introduced in lessons | 70% |

## 3.4. Indicator 4: Impact of emerging technologies on efficiency and innovation

The introduction of new technologies in the maritime sector, including automation, AI-based navigation systems, and fuel-efficient engines, has had a profound effect on operational efficiency and innovation. The professionals in the maritime industry reported that these technologies are essential for reducing operational costs, improving safety, and achieving sustainability goals. However, the integration of these technologies into vocational education has been slow.

The results demonstrate that the use of automation and AI-based systems has greatly improved the operational efficiency of maritime businesses (Table 4). However, the integration of these technologies into academic programs has not yet fully caught up with industry demands. The lecturers noted that while some courses cover the basics of these systems, there is a need for more comprehensive training and hands-on experience for students.

**Table 4. Emerging technology impact.**

| Technology Type | Efficiency Improvement (Industry) | Academic Integration (Lecturers) | Innovation Score (%) |
|---|---|---|---|
| **Automation Systems** | Significant improvements in operations | Partially covered in advanced courses | 85% |
| **AI-based Navigation** | Increasing reliance for route optimisation | Not yet fully included in curricula | 70% |
| **Fuel-efficient Engines** | Substantial fuel savings and emissions reductions | Core topic in engine studies | 90% |
| **Digital Twin Simulations** | Useful for training and planning | Limited availability | 65% |

## 3.5. Indicator 5: Challenges and opportunities in enhancing maritime engineering education

The final key result of this study was the identification of both challenges and opportunities for enhancing maritime engineering education. Educators expressed concerns about resource limitations and the rapid pace of technological advancement. Many noted that while they were eager to update their curricula, the necessary resources (such as access to the latest technologies and training equipment) were not always available. Conversely, professionals identified

numerous opportunities for collaboration between educational institutions and industry to close these gaps.

Table 5 highlights the need for a greater focus on resources and the frequency of curriculum updates. The feasibility score indicates that while there are significant challenges, the opportunities for collaboration and joint initiatives between education and industry are promising avenues for improvement.

**Table 5. Challenges and opportunities.**

| Aspect | Challenges (Lecturers) | Opportunities (Professionals) | Feasibility Score (%) |
|---|---|---|---|
| **Resource Availability** | Limited access to emerging tech | Industry partnerships for resource sharing | 65% |
| **Curriculum Update Frequency** | Lagging behind industry requirements | Increased collaboration with industry | 75% |
| **Access to Practical Training** | Geographic and financial limitations | Joint training programs with companies | 80% |
| **Teacher Training and Development** | Insufficient professional development | Opportunities for upskilling | 70% |

## 4. Discussion

This research provides a comprehensive analysis of the intersection between emerging technologies, sustainability, and vocational training in maritime engineering education. The findings reveal critical gaps between industry advancements and educational practices, underscoring the need for an updated curriculum that incorporates both technological proficiency and sustainable practices. Such alignment is crucial to preparing a skilled workforce capable of navigating the rapidly evolving maritime sector [1, 2].

A key finding is the importance of integrating emerging technologies, such as AI-driven navigation and automation systems, into vocational training. These technologies have already demonstrated substantial impacts on operational efficiency and safety within the maritime industry, yet many vocational programs lag in offering students exposure to these tools [4, 6]. Educators in this study noted that while foundational engineering principles are well-covered, curricula often lack the resources and agility to incorporate new technologies promptly, leading to a misalignment between educational outcomes and industry expectations. This gap supports findings that emphasize the role of continuous curriculum updates in preparing students for technologically sophisticated roles [5].

Sustainability emerged as a prominent theme, with industry professionals and educators agreeing on its importance but recognizing challenges in fully integrating it into maritime education. Industry stakeholders identified eco-friendly technologies, such as energy-efficient engines and waste-reduction systems, as essential for reducing emissions and operational costs. However, educational programs have only gradually incorporated sustainability concepts, often limited to theoretical coverage rather than practical applications [1]. Previous studies highlight that while sustainability has become a priority in maritime operations, vocational programs must increase practical exposure to green technologies to ensure students gain hands-on experience in sustainable practices [3, 6].

Soft skills, including problem-solving and adaptability, were also identified as underemphasized yet essential for maritime graduates. Participants in the study noted that while students are generally proficient in technical knowledge, their ability to apply these skills in dynamic, real-world situations requires improvement. This finding aligns with research that highlights the growing need for critical thinking and adaptability in technical fields, particularly as industries become more reliant on digital and automated systems [8].

To bridge these gaps, closer collaboration between educational institutions and industry is essential. Internationally, partnerships between maritime education institutions and industry have proven effective in creating adaptive training environments and facilitating curriculum updates. Examples from Norway and Japan demonstrate that joint training programs, industry-sponsored laboratories, and real-world internships allow students to engage directly with current technologies and industry practices [5, 9]. Such partnerships could serve as a model for Indonesia's vocational maritime programs, enabling them to provide students with exposure to industry-relevant tools and practices and improve the alignment of educational outcomes with industry needs.

## 5. Conclusion

This research highlights the critical importance of aligning maritime engineering education with emerging technologies and industry demands. Through qualitative insights from maritime professionals and educators, it is clear that vocational programs in Indonesia must evolve to incorporate sustainable engineering practices, advanced technologies such as automation and AI, and real-world problem-solving skills. The research emphasizes that while the maritime industry is embracing green technologies and operational efficiencies, educational institutions are lagging in integrating these advancements into their curricula. Collaborative partnerships between industry and education are essential to bridge this gap, providing students with practical, hands-on experience and ensuring they are equipped with the skills needed for modern maritime engineering roles. Additionally, there is an urgent need for vocational programs to emphasize sustainability, critical thinking, and adaptability to ensure that graduates contribute effectively to a rapidly evolving industry. Enhancing engineering technology and education in maritime studies not only benefits individual students and industries but also supports Indonesia's broader goals for economic growth and global competitiveness in the maritime sector.

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