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| Integration of STEM Education in Maritime Training: A Comparative Analysis*April Gunawan Malau1)* *aprilgunawan22@gmail.com**Rosna Yuherlina Siahaan2) rosnalina@gmail.com**Marudut Bernadtua Simanjuntak3)* *bernadmarudut@gmail.com**Albert Gamot Malau4)* *albert@ecampus.ut.ac.id**Jan Hotman5) hotman@ecampus.ut.ac.id**Nyaris Pambudiyatno6)* *n.pambudi@gmail.com**Sutrisno Sutrisno7)* *christdeon@gmail.com**1,2,3 Maritime Institute of Jakarta (Sekolah Tinggi Ilmu Pelayaran - Jakarta)**4,5 Open University - School of Science and Technology (Universitas Terbuka)**6Aviation Polytechnic of Surabaya**7Moriah Theological Seminary (STT Moriah - Tangerang)* |

***Abstract***

*This research delves into the integration of STEM Education in Nautical and Technical Majors among junior cadets in maritime institutes, Private Maritime Institutes, and vocational institutions. Through qualitative analysis, including participant interviews and document scrutiny, the study explores challenges, opportunities, and implications within the maritime education sector. Findings reveal a majority perception of alignment with international standards, emphasizing the importance of preparing students to meet industry requirements outlined by the International Maritime Organization's Standards of Training, Certification, and Watchkeeping (STCW) convention. Identified needs encompass practical training opportunities, technological integration, industry exposure, and soft skills development, highlighting the evolving nature of the maritime industry and the demands placed on future professionals. Moreover, the study underscores the significance of professionalism in maritime education, emphasizing the cultivation of a culture of excellence, integrity, and ethical behavior among students. The research contributes to ongoing discourse surrounding maritime education reform, curriculum development, and professionalization efforts, offering insights to enhance the quality, relevance, and effectiveness of maritime education programs.*

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| *Keywords : STEM Education, Maritime Training, Integration, International Standards, Professionalism* |

1. **INTRODUCTION**

The integration of Science, Technology, Engineering, and Mathematics (STEM) education has garnered significant attention in recent years, particularly within specialized fields such as Nautical and Technical majors. As we navigate through the complexities of the modern world, the demand for skilled professionals equipped with interdisciplinary knowledge and problem-solving skills has become increasingly pronounced [1]. In response to this paradigm shift, educational institutions, particularly those specializing in maritime education, marine engineering, and vocational training, are reassessing their pedagogical approaches to align with international standards and industry requirements [2]. The maritime sector, characterized by its dynamic nature and technological advancements, necessitates a workforce capable of adapting to evolving challenges and embracing innovative solutions. Recognizing this imperative, educational stakeholders have embarked on initiatives to integrate STEM education into nautical and technical majors, thereby equipping students with the competencies essential for success in the maritime industry [3], [4]. This integration is not merely a pedagogical strategy but a strategic imperative to bridge the gap between academic knowledge and practical application, fostering a generation of professionals poised to navigate the complexities of maritime operations effectively.

Against this backdrop, the present research embarks on a critical inquiry into the Integration of STEM Education in Nautical and Technical Majors: A Comparative Analysis. This study is situated within the context of maritime institutes, Private Maritime Institutes, and vocational institutions, which serve as crucibles for nurturing the next generation of maritime professionals [5]. By undertaking a qualitative research approach coupled with descriptive analysis, this research seeks to unravel the intricacies of STEM integration within the specialized domains of nautical and technical majors. The impetus for this research stems from the imperative to understand and enhance educational practices tailored to meet the demands of contemporary maritime industries. With the globalization of maritime trade and the proliferation of technological innovations, there exists a pressing need to equip students with a holistic skill set encompassing scientific inquiry, technological proficiency, engineering principles, and mathematical acumen. However, the efficacy of STEM integration within nautical and technical majors remains a subject of inquiry, warranting a nuanced examination of pedagogical approaches and curricular frameworks across diverse educational settings.

The overarching purpose of this research is twofold: firstly, to critically evaluate the implementation of STEM education in nautical and technical majors; and secondly, to offer insights into enhancing educational practices and curriculum development aligned with international standards, particularly those prescribed by the International Maritime Organization (IMO) through its Standards of Training, Certification, and Watchkeeping (STCW) convention [6], [7]. By elucidating the strengths and weaknesses of existing integration efforts, this research endeavors to inform strategic interventions aimed at optimizing STEM education delivery and fostering a conducive learning environment conducive to the holistic development of maritime professionals. Moreover, this research is underpinned by a comparative analysis framework, which seeks to juxtapose STEM integration across different educational institutions. The inclusion of forty-five junior cadets from diverse educational backgrounds serves as a cornerstone for this comparative analysis, enabling a nuanced understanding of the variations in STEM implementation strategies, pedagogical approaches, and student outcomes. Through this comparative lens, this research aims to discern best practices, identify challenges, and propose recommendations to enhance the efficacy and sustainability of STEM integration initiatives within nautical and technical majors.

The integration of STEM education in nautical and technical majors represents a multifaceted endeavor aimed at preparing students for the rigors of contemporary maritime industries. By delving into the nuances of STEM integration through a comparative analysis lens, this research endeavors to contribute to the ongoing discourse surrounding educational reform and curriculum development within specialized fields. Through critical inquiry and evidence-based analysis, this research aspires to offer actionable insights that can inform policy decisions, pedagogical practices, and curriculum design, thereby fostering a generation of maritime professionals equipped to navigate the complexities of the maritime domain with competence and confidence.

1. **METHOD**

The present research adopts a qualitative approach to investigate the integration of STEM Education in Nautical and Technical Majors among junior cadets. This section delineates the research design, data collection methods, participant selection criteria, and data analysis techniques employed in the study [8], [9]. The qualitative research design is well-suited for exploring complex phenomena within their natural context, allowing for an in-depth understanding of participants' perspectives, experiences, and behaviors. In this study, qualitative methods are employed to elucidate the nuances of STEM integration in nautical and technical majors, offering rich insights into the challenges, successes, and areas for improvement within educational settings.

Data collection primarily comprises semi-structured interviews and document analysis [10], [11]. Semi-structured interviews enable researchers to engage in open-ended dialogue with participants, probing into their perceptions, attitudes, and experiences regarding STEM integration in their educational journey [12]. These interviews are conducted in a conversational manner, allowing participants to articulate their thoughts and reflections freely. Additionally, document analysis involves scrutinizing educational materials, curricular documents, and institutional policies related to STEM education, providing contextual information and triangulating findings from interviews. The study targets junior cadets enrolled in maritime institutes, Private Maritime Institutes, and vocational institutions, reflecting the diverse spectrum of educational settings within the maritime domain [13]. The selection criteria encompass cadets currently undergoing training in nautical and technical majors, ensuring relevance to the research topic. A purposive sampling approach is employed to recruit participants based on their educational background, academic performance, and willingness to participate in the study. The inclusion of junior cadets offers a unique perspective on STEM integration, capturing the experiences of emerging professionals poised to enter the maritime industry.

Data analysis is conducted iteratively, employing thematic analysis to identify recurring patterns, themes, and sub-themes within the qualitative data [12]. Thematic analysis involves systematically organizing and categorizing interview transcripts and documentary evidence, followed by the identification of overarching themes that encapsulate participants' perspectives on STEM integration. Through a process of coding, categorization, and interpretation, the researcher extracts meaningful insights from the data, facilitating a nuanced understanding of the research phenomenon. The iterative nature of thematic analysis allows for reflexivity and validation of emerging themes, ensuring rigor and reliability in the interpretation of findings.

1. **RESULT AND DISCUSSION**

**3.1. Result**

The findings of the research offer valuable insights into the integration of STEM Education in Nautical and Technical Majors among junior cadets. Through a qualitative analysis of semi-structured interviews and document analysis, coupled with thematic analysis, the study elucidates the perspectives, experiences, and challenges faced by participants in navigating STEM education within the maritime domain.

**Participant Demographics:** The study comprised 45 junior cadets from diverse educational backgrounds, enrolled in maritime institutes, Private Maritime Institutes, and vocational institutions. Table 1 provides an overview of the demographic characteristics of the participants.

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| **Demographic** | **Frequency** | **Percentage** |
| Gender |  |  |
| - Male | 32 | 71.1% |
| - Female | 13 | 28.9% |
| **Educational Level** |
| - Nautical Major | 20 | 44.4% |
| - Technical Major | 25 | 55.6% |
| **Institution Type** |
| - Maritime Institute | 15 | 33.3% |
| - Private Maritime Institute | 20 | 44.4% |
| - Vocational School | 10 | 22.2% |

**Perceptions of STEM Integration:** Participants expressed varying perceptions regarding the integration of STEM education in their respective majors. Table 2 illustrates the distribution of responses based on participants' perceptions.

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| **Perception** | **Frequency** | **Percentage** |
| Positive | 27 | 60.0% |
| Neutral | 12 | 26.7% |
| Negative | 6 | 13.3% |

The majority of participants (60.0%) held positive perceptions of STEM integration, citing its relevance to their future careers, enhancement of critical thinking skills, and alignment with industry demands. However, a notable proportion (13.3%) expressed negative perceptions, highlighting challenges such as inadequate resources, lack of qualified instructors, and disconnect between theoretical learning and practical application.

**Challenges of STEM Integration:** Participants identified several challenges associated with STEM integration in nautical and technical majors. Table 3 presents the distribution of challenges reported by participants.

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| **Challenges** | **Frequency** | **Percentage** |
| Inadequate Resources | 18 | 40.0% |
| Lack of Qualified Instructors | 15 | 33.3% |
| Theoretical-Practical Divide | 12 | 26.7% |
| Curriculum Rigidity | 8 | 17.8% |
| Technological Infrastructure | 6 | 13.3% |

The most prevalent challenge reported by participants was inadequate resources, including limited laboratory facilities, outdated equipment, and insufficient instructional materials. This was followed closely by the lack of qualified instructors capable of delivering STEM-focused instruction effectively. Additionally, participants highlighted the disconnect between theoretical learning and practical application, suggesting a need for greater integration of hands-on learning experiences into the curriculum.

**Impact of STEM Integration on Learning Outcomes:** Participants reflected on the impact of STEM integration on their learning outcomes and skill development. Table 4 illustrates the distribution of responses regarding the perceived impact of STEM integration.

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| **Impact on Learning Outcomes** | **Frequency** | **Percentage** |
| Positive | 25 | 55.6% |
| Neutral | 12 | 26.7% |
| Negative | 8 | 17.8% |

The majority of participants (55.6%) reported a positive impact of STEM integration on their learning outcomes, citing improvements in problem-solving abilities, critical thinking skills, and practical competency. However, a notable proportion (17.8%) expressed negative perceptions, indicating challenges such as increased workload, difficulty in grasping complex STEM concepts, and lack of support mechanisms.

**Suggestions for Improvement:** Participants offered valuable suggestions for enhancing STEM integration in nautical and technical majors. Table 5 presents the distribution of suggestions provided by participants.

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| **Suggestions** | **Frequency** | **Percentage** |
| Increase Resource Allocation | 20 | 44.4% |
| Enhance Teacher Training | 15 | 33.3% |
| Foster Interdisciplinary Collaboration | 12 | 26.7% |
| Promote Hands-on Learning Experiences | 10 | 22.2% |

The most frequently cited suggestion was to increase resource allocation, including investment in laboratory facilities, technology upgrades, and provision of adequate instructional materials. Participants also emphasized the importance of enhancing teacher training to ensure educators are equipped with the necessary pedagogical skills and subject expertise. Furthermore, fostering interdisciplinary collaboration and promoting hands-on learning experiences emerged as key recommendations for enriching STEM education delivery.

The findings of the research offer valuable insights into the integration of STEM Education in Nautical and Technical Majors among junior cadets. Despite the challenges identified, participants generally perceive STEM integration positively and recognize its potential to enhance learning outcomes and prepare them for future careers in the maritime industry. By addressing the challenges highlighted and implementing the suggested improvements, educational institutions can optimize STEM integration initiatives, thereby equipping students with the requisite skills and competencies demanded by the contemporary maritime domain.

Delved deeper into the analysis of research findings, needs, and professionalism within the maritime education sector, with a focus on supporting and empowering the integration of STEM Education in Nautical and Technical Majors. The data presented here are derived from participant responses, document analysis, and thematic analysis, aimed at elucidating the challenges and opportunities inherent in aligning educational practices with international standards, specifically those prescribed by the International Maritime Organization (IMO) through its Standards of Training, Certification, and Watchkeeping (STCW) convention.

**Alignment with International Standards:** Participants emphasized the importance of aligning educational practices with international standards, particularly the STCW convention, which serves as the benchmark for maritime education and training worldwide. Table 1 provides an overview of participants' perceptions regarding the alignment of their educational experiences with international standards.

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| **Alignment with International Standards** | **Frequency** | **Percentage** |
| Aligned | 30 | 66.7% |
| Partially Aligned | 10 | 22.2% |
| Not Aligned | 5 | 11.1% |

The majority of participants (66.7%) perceived their educational experiences as aligned with international standards, indicating that their programs encompassed the requisite STCW competencies and curriculum components. However, a significant proportion (22.2%) reported partial alignment, citing gaps in certain areas such as practical training, technological integration, and industry exposure. A smaller subset of participants (11.1%) indicated that their educational experiences were not aligned with international standards, underscoring the need for comprehensive reform and curriculum enhancement initiatives.

**Identification of Needs:** Participants identified several key areas of need within the maritime education sector, which are essential for fostering professionalism and competency among future maritime professionals. Table 2 presents the distribution of identified needs reported by participants.

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| **Identified Needs** | **Frequency** | **Percentage** |
| Practical Training Opportunities | 25 | 55.6% |
| Technological Integration | 20 | 44.4% |
| Industry Exposure | 18 | 40.0% |
| Soft Skills Development | 15 | 33.3% |

The most commonly cited need was for practical training opportunities, including onboard experience, simulation exercises, and hands-on workshops, to complement theoretical instruction and enhance practical competency. Participants also highlighted the importance of technological integration, emphasizing the need for access to state-of-the-art equipment, software tools, and digital learning resources to stay abreast of technological advancements in the maritime industry. Furthermore, industry exposure emerged as a critical need, with participants advocating for internships, industry partnerships, and guest lectures to provide insights into real-world maritime operations. Additionally, there was a recognized need for soft skills development, including communication, teamwork, leadership, and problem-solving skills, to complement technical proficiency and enhance overall professionalism among maritime professionals.

**Professionalism in Maritime Education:** The concept of professionalism permeated discussions surrounding maritime education, reflecting the industry's stringent standards and expectations for future maritime professionals. Table 3 illustrates participants' perceptions regarding the importance of professionalism in their educational journey.

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| **Importance of Professionalism** | **Frequency** | **Percentage** |
| Very Important | 35 | 77.8% |
| Somewhat Important | 8 | 17.8% |
| Not Important | 2 | 4.4% |

The overwhelming majority of participants (77.8%) deemed professionalism to be of utmost importance in their educational journey, recognizing its significance in shaping their conduct, attitudes, and work ethic as future maritime professionals. Only a small minority (4.4%) perceived professionalism as not important, highlighting a prevailing ethos of excellence and adherence to professional standards within the maritime education community.

The analysis of research findings underscores the interplay between STEM integration, international standards, identified needs, and professionalism within the maritime education sector. By aligning educational practices with international standards, particularly those outlined by the STCW convention, educational institutions can ensure that their programs meet industry requirements and equip students with the competencies needed for success in the maritime profession. Moreover, addressing the identified needs, such as providing practical training opportunities, integrating technology into the curriculum, facilitating industry exposure, and fostering soft skills development, is essential for nurturing well-rounded maritime professionals capable of navigating the complexities of the maritime domain with professionalism and competence.

The findings highlight the imperative for holistic reform and continuous improvement initiatives within the maritime education sector to meet the evolving demands of the industry and uphold the highest standards of professionalism. By addressing the identified needs and embracing STEM integration in line with international standards, educational institutions can empower future generations of maritime professionals to excel in their careers and contribute to the advancement of the maritime industry on a global scale.

**3.2. Discussion**

 The discussion section synthesizes and interprets the findings presented in the previous sections, elucidating the implications, significance, and broader implications of the research on the integration of STEM Education in Nautical and Technical Majors among junior cadets. By examining the alignment with international standards, identifying needs within the maritime education sector, and analyzing the importance of professionalism, this discussion seeks to provide a comprehensive understanding of the research findings and their implications for educational practice, policy, and future research endeavors.

**Alignment with International Standards:** The findings indicate that a majority of participants perceive their educational experiences as aligned with international standards, particularly those outlined by the International Maritime Organization's (IMO) Standards of Training, Certification, and Watchkeeping (STCW) convention [14]–[16]. This alignment is essential for ensuring that maritime education programs meet industry requirements and equip students with the competencies necessary for success in the maritime profession. However, the presence of partial alignment and instances of non-alignment underscore the need for ongoing efforts to enhance curriculum development, instructional practices, and institutional policies to align more closely with international standards. Educational institutions must prioritize alignment with the STCW convention to ensure that graduates are adequately prepared to meet the demands of the global maritime industry and contribute effectively to maritime operations, safety, and sustainability [7].

**Identification of Needs:** The research findings highlight several key areas of need within the maritime education sector, including the provision of practical training opportunities, technological integration, industry exposure, and soft skills development [4]. These needs reflect the evolving nature of the maritime industry and the demands placed on future maritime professionals to possess a diverse skill set encompassing technical proficiency, problem-solving abilities, and interpersonal skills. Addressing these needs requires collaborative efforts among educational institutions, industry stakeholders, and regulatory bodies to develop comprehensive strategies and initiatives that promote experiential learning, foster technological innovation, facilitate industry engagement, and cultivate professionalism among maritime professionals [17]. By prioritizing these areas of need, educational institutions can enhance the quality and relevance of maritime education programs, thereby better preparing students for successful careers in the maritime industry.

**Professionalism in Maritime Education:** The findings underscore the importance of professionalism in maritime education, with the overwhelming majority of participants recognizing its significance in shaping their conduct, attitudes, and work ethic as future maritime professionals [18], [19]. Professionalism encompasses a range of attributes, including integrity, accountability, reliability, and adherence to ethical standards, which are essential for maintaining safety, efficiency, and integrity within the maritime industry. Educational institutions play a crucial role in fostering professionalism among students by instilling a culture of excellence, emphasizing the importance of ethical behavior, and providing opportunities for professional development and growth. By promoting professionalism within the educational environment, institutions can empower students to become responsible, ethical, and conscientious maritime professionals capable of upholding the highest standards of conduct and contributing positively to the maritime industry [20].

**Implications for Educational Practice and Policy:** The research findings have several implications for educational practice and policy within the maritime education sector. Firstly, educational institutions must prioritize alignment with international standards, particularly the STCW convention, to ensure that their programs meet industry requirements and prepare students for successful careers in the maritime industry [7]. This may entail revising curriculum frameworks, enhancing instructional practices, and investing in faculty development initiatives to align more closely with international standards and best practices in maritime education. Secondly, addressing the identified needs within the maritime education sector requires a multifaceted approach that involves collaboration among educational institutions, industry stakeholders, and regulatory bodies. This may include expanding practical training opportunities, integrating technology into the curriculum, establishing industry partnerships, and implementing soft skills development programs to enhance the overall quality and relevance of maritime education programs [21]. Thirdly, promoting professionalism within the educational environment is essential for nurturing ethical, responsible, and conscientious maritime professionals. Educational institutions must prioritize the cultivation of professionalism through curricular and extracurricular activities, mentorship programs, and opportunities for professional development and growth. By instilling a culture of professionalism within the educational setting, institutions can prepare students to navigate the complexities of the maritime industry with integrity, competence, and confidence.

**Future Research Directions:** While the present research offers valuable insights into the integration of STEM Education in Nautical and Technical Majors among junior cadets, several avenues for future research merit consideration. Firstly, longitudinal studies tracking the career trajectories and professional outcomes of graduates from maritime education programs could provide valuable insights into the long-term impact of STEM integration on career success and industry contributions. Secondly, comparative studies examining STEM integration initiatives across different educational settings, geographic regions, and cultural contexts could offer insights into the factors influencing the effectiveness and sustainability of STEM integration efforts. Additionally, qualitative studies exploring the perspectives and experiences of industry stakeholders, including employers, maritime professionals, and regulatory authorities, could provide valuable insights into the alignment between educational outcomes and industry expectations. By addressing these research gaps, future studies can contribute to the ongoing discourse surrounding maritime education reform, curriculum development, and professionalization efforts within the maritime industry.

The discussion highlights the significance of the research findings on the integration of STEM Education in Nautical and Technical Majors among junior cadets for educational practice, policy, and future research endeavors within the maritime education sector. By aligning with international standards, addressing identified needs, promoting professionalism, and exploring future research directions, educational institutions can enhance the quality, relevance, and effectiveness of maritime education programs, thereby better preparing students for successful careers in the maritime industry.

1. **CONCLUSION**

The research on the integration of STEM Education in Nautical and Technical Majors among junior cadets has provided valuable insights into the challenges, opportunities, and implications within the maritime education sector. Through qualitative analysis, participant interviews, and document scrutiny, the study has illuminated the complex interplay between STEM integration, international standards, identified needs, and professionalism, shedding light on the multifaceted nature of educational practices and policy within the maritime domain. The findings underscore the importance of aligning educational practices with international standards, particularly those outlined by the International Maritime Organization's (IMO) Standards of Training, Certification, and Watchkeeping (STCW) convention, to ensure that maritime education programs meet industry requirements and equip students with the competencies necessary for success in the maritime profession. The identification of needs within the maritime education sector, including the provision of practical training opportunities, technological integration, industry exposure, and soft skills development, highlights the evolving nature of the maritime industry and the demands placed on future maritime professionals to possess a diverse skill set.

Moreover, the emphasis on professionalism within maritime education underscores the importance of fostering a culture of excellence, integrity, and ethical behavior among students, preparing them to navigate the complexities of the maritime industry with competence and confidence. By addressing these challenges and opportunities, educational institutions can enhance the quality, relevance, and effectiveness of maritime education programs, thereby better preparing students for successful careers in the maritime industry. Moving forward, future research endeavors should focus on longitudinal studies tracking the career trajectories of graduates from maritime education programs, comparative studies examining STEM integration initiatives across different educational settings, and qualitative studies exploring the perspectives of industry stakeholders. By addressing these research gaps, future studies can contribute to the ongoing discourse surrounding maritime education reform, curriculum development, and professionalization efforts within the maritime industry. The research on the integration of STEM Education in Nautical and Technical Majors among junior cadets has significant implications for educational practice, policy, and future research endeavors within the maritime education sector. By aligning with international standards, addressing identified needs, promoting professionalism, and exploring future research directions, educational institutions can enhance the quality, relevance, and effectiveness of maritime education programs, thereby better preparing students for successful careers in the maritime industry.

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