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Enhancing Technical Competency in Naval Engine Systems through Industry-Based Learning in Maritime Vocational Education

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Abstract

This research explores the enhancement of technical competency in naval engine systems through industry-based learning approaches within maritime vocational education. Employing a qualitative descriptive method, the study involved two participant groups: experienced maritime professionals with over 20 years of sea service who now serve in managerial, advisory, and auditing roles in port and shipping industries, and ten vocational lecturers with sea-going experience and extensive teaching expertise in marine engineering. Findings revealed a substantial gap between classroom-based theoretical instruction and the practical realities of engine room operations. Contributing factors include outdated curricula, limited industry engagement in teaching processes, and insufficient access to real-life engine room practice. Both professionals and educators highlighted the urgency of integrating experiential learning models to align educational outcomes with industry demands. The study emphasizes the need for curriculum reform grounded in real-world operations, competency-based assessment methods, and structured mentorship from industry practitioners. By bridging the disconnect between institutional instruction and shipboard operations, this research contributes a strategic framework for developing adaptive, skilled, and industry-ready maritime graduates in engine systems.

1. INTRODUCTION

The maritime industry, as one of the world's most critical sectors in global trade and logistics, demands not only infrastructural excellence but also a highly competent workforce capable of navigating the complexities of maritime technologies, particularly in the field of naval engine systems [1]–[3]. Vocational maritime education plays a pivotal role in shaping future seafarers and maritime engineers, especially those who operate and maintain propulsion systems, engine rooms, and auxiliary machinery of vessels. Yet, despite global and regional initiatives to enhance maritime capacity, there exists a persistent gap between what is taught in maritime vocational institutions and the realities encountered in the field—especially in engine-related technical competencies. The increasing technological complexity of ship machinery systems and the transition toward greener, sustainable marine engineering underscore the urgency for maritime education to adapt swiftly and efficiently to these dynamic industrial trends [4].

The current structure of maritime vocational education, particularly in naval engine systems, often leans heavily on curriculum-bound training modules that prioritize theoretical knowledge, sometimes at the expense of experiential depth [5], [6]. While simulation labs, workshops, and institutional training centers attempt to replicate real-world settings, they fall short of fully immersing students in the unpredictable and high-stakes environment of engine rooms at sea [7]. Consequently, graduates frequently enter the workforce with commendable academic understanding but struggle to adapt to on-board operational realities, leading to increased onboarding times, reduced efficiency in early career stages, and sometimes compromising

safety or operational standards. This research arises from that concern—how to meaningfully bridge the pedagogical gap between classroom knowledge and engine room performance, particularly through the integration of qualitative experiences from seasoned professionals and dedicated maritime lecturers.

The evolution of naval engines from conventional diesel propulsion systems to hybrid and green technologies has also dramatically reshaped the competencies expected of maritime engineering graduates [3], [8]. It is no longer sufficient to understand traditional thermodynamics or mechanical processes alone; graduates must now demonstrate interdisciplinary acumen that encompasses environmental compliance, emissions regulation, digital monitoring systems, and energy optimization. Industry stakeholders—ranging from port authorities to private shipping corporations—have expressed dissatisfaction with the rigidity of vocational training structures that fail to produce technically versatile and operationally adaptive marine engineers. This growing discord between industrial demands and educational outputs calls for a thorough reevaluation of how vocational maritime institutions prepare cadets and trainees for engine system management in real maritime settings.

A crucial, yet underutilized, source of insight into this challenge lies in the lived experiences of maritime professionals who have spent decades navigating shipboard engine operations and later transitioned into management, audit, or advisory roles. These professionals carry embedded knowledge—often tacit and deeply contextual—that cannot be captured through textbooks or technical manuals alone [9], [10]. Similarly, maritime lecturers and trainers who have both teaching experience and sea-going exposure possess a unique duality of perspective, blending pedagogical insight with real-world application. Their reflections on student readiness, curriculum design, and training limitations offer a fertile ground for constructing a more adaptive and effective educational framework [11]. However, academic maritime research has rarely captured these voices systematically, particularly through qualitative exploration. This research seeks to fill that void by rigorously documenting and analyzing the perspectives of both groups: experienced seafarers and vocational maritime educators.

At the heart of this research is the conviction that industry-based learning—rooted in real-life maritime operations and reflective of authentic engine system challenges—is a transformative pathway to enhance the technical competency of maritime students. Industry-based learning is not merely about field visits or internships; it is about structurally embedding the logic, rhythm, and expectations of shipboard engine work into the pedagogical architecture of vocational training [1], [12], [13]. Such a model requires not only curriculum redesign but also the active involvement of industry professionals as co-educators, mentors, and evaluators. The research explores how this integration can occur in the context of naval engine systems, which form the mechanical heart of every vessel and represent a complex interplay of systems thinking, manual skill, environmental responsibility, and safety adherence.

This study also explores the narratives of veteran maritime professionals who now serve as advisors, entrepreneurs, or senior officers in port and shipping enterprises. Having spent more than twenty years at sea, these individuals offer nuanced understandings of how engine room tasks evolve, how emergencies are managed, and how leadership and mentorship occur on board—often in high-pressure, cross-cultural environments. Their ability to recall and articulate experiential learning, crisis management, and adaptive decision-making presents invaluable data for designing educational interventions that are resilient and realistic. In parallel, the insights of ten lecturers with over five years of sea service and extensive experience teaching cadets illuminate the disconnects between simulation-based training and onboard realities. Their feedback on curriculum implementation, student motivation, and pedagogical bottlenecks adds a crucial dimension to this qualitative exploration.

This research is urgent for several reasons. First, global maritime standards continue to evolve rapidly, particularly with the rise of decarbonization mandates and digitalization in engine monitoring and reporting. Second, there is an increasing emphasis on outcome-based education models that prioritize demonstrable competence over seat-time or credit accumulation. Third, the maritime labor market faces a paradox of simultaneous unemployment and unfilled vacancies—largely because vocational training does not match job requirements. This mismatch is especially pronounced in the domain of engine operations, where automation, environmental accountability, and fuel efficiency demand highly specialized skill sets that many new graduates lack. Without urgent reform, maritime vocational institutions risk producing graduates who are technically obsolete upon entry into the workforce.

The novelty of this research lies in its methodological and thematic approach. Rather than relying on surveys or institutional statistics, the study uses in-depth qualitative interviews and thematic analysis to surface deep insights into technical competency development. It focuses narrowly but intensively on naval engine systems—a domain often overlooked in maritime education research, which tends to favor

navigational or managerial themes. By focusing on narrative-rich data from professionals and lecturers, this research elevates the value of practice-based knowledge and challenges the dominance of abstract theory in curriculum design. Moreover, it proposes a grounded framework for integrating industry-based learning into technical maritime training, offering actionable insights for curriculum developers, institutional leaders, and policy architects in maritime education.

The study's focus on qualitative comprehension is not merely methodological but philosophical: it embraces the complexity, ambiguity, and contextual richness of professional learning. Engine room expertise is not simply a function of memorized procedures but a dynamic interplay of situational awareness, decision-making, teamwork, and ethical responsibility. These attributes are cultivated over time through real-world exposure and reflective learning. The challenge, then, is how vocational education can approximate or simulate these conditions effectively. This study's findings aim to inform the design of such simulations, training modules, and industry linkages.

This research also contributes to the broader discourse on maritime sustainability by emphasizing human competency as a pillar of safe and responsible engine operations [14], [15]. Engine failures, maintenance lapses, and energy inefficiencies often stem from human error or inadequate training [2]. By enhancing the technical education of engine officers and mechanics, maritime institutions contribute indirectly but significantly to environmental protection, economic efficiency, and crew safety. In this sense, the research supports not only educational innovation but also sustainable maritime development, aligning with international goals of safe seas and resilient marine transport systems.

This study offers an in-depth, reflective, and actionable inquiry into how maritime vocational education, particularly in naval engine systems, can evolve through the integration of industry-based learning. It brings together the experiential wisdom of maritime professionals and the pedagogical expertise of lecturers to inform a new model of technical training. Through this effort, the study seeks to transform vocational maritime education from a compliance-oriented enterprise into a dynamic, industry-responsive, and competency-driven system that empowers students to navigate the engine rooms of the future with confidence, precision, and adaptability.

2. RESEARCH METHOD

This study adopts a qualitative research design with a descriptive and exploratory approach to deeply examine the enhancement of technical competencies in maritime vocational education, particularly in the field of naval engine systems. The aim is to capture and interpret the lived experiences, insights, and pedagogical reflections of maritime professionals and lecturers who have engaged directly with maritime education and engine operations. The research does not seek to quantify but to interpret and understand patterns of meaning, practices, and challenges from the perspectives of those embedded in the field [16], [17]. The qualitative nature of the study is grounded in the understanding that technical skill development in maritime education is a contextual, experience-based, and dynamic process that cannot be reduced to numerical indicators alone. Therefore, the methodological orientation emphasizes depth, narrative richness, and thematic interpretation [18], [19]. Through this approach, the research uncovers the nuances of vocational education practices, identifies barriers to competency development, and proposes strategies for aligning instructional methods with real-world maritime demands.

The primary participants of this research consist of two groups: (1) maritime professionals with over two decades of sea-going experience who have transitioned into managerial, advisory, or entrepreneurial roles within the port and shipping industry, and (2) ten maritime lecturers with both academic and practical backgrounds in marine engineering who have taught cadets for more than eight years and previously served at sea for a minimum of five years. The inclusion of both practitioners and educators enables a balanced representation of both industrial expectations and educational strategies.

Participant selection was conducted purposively, based on the relevance of their background to the study's focus. The professionals involved are known for their expertise in naval engine systems and their advisory roles in shipping operations. The lecturers, selected from various maritime vocational institutions, are those actively involved in curriculum implementation and student training for marine machine systems. Their dual roles as educators and former practitioners ensure that their insights are both reflective and grounded in real engine room experiences.

Data collection was carried out through semi-structured in-depth interviews and focus group discussions. The interviews allowed for open-ended responses, enabling participants to elaborate on their experiences, observations, and suggestions. Interview guides were designed around key thematic areas such as

curriculum relevance, practical training adequacy, simulation effectiveness, instructional methods, and perceived gaps between institutional education and operational practice. Each session was recorded and transcribed to ensure the accuracy of data representation. To complement the interviews, field notes were taken during informal conversations and institutional observations, offering contextual background for the analysis.

Prior to full deployment, interview instruments were piloted with a small number of maritime educators to ensure clarity and relevance [20]. This stage helped refine the structure and flow of the interview questions, allowing for a more focused exploration of the research themes during actual data collection. Ethical considerations were strictly maintained, including informed consent, confidentiality, and the right to withdraw at any stage of participation.

The data analysis process employed thematic analysis as the principal technique. Transcripts from interviews and discussions were first read multiple times to develop familiarity with the content. Initial coding was conducted to identify recurring patterns, statements, and concepts. These codes were then grouped into broader categories or themes reflecting the major issues and insights emerging from the data. Examples of potential themes include experiential gaps in engine training, the role of simulation, industry expectations, and instructional constraints. Coding was both inductive—emerging from the data itself—and deductive—guided by the research questions.

To ensure reliability and trustworthiness, the analysis process involved member checking, whereby participants were invited to review and validate the summaries of their input. Peer debriefing among research team members helped to cross-examine interpretations and reduce individual bias. Triangulation was achieved by comparing data across different participant groups and institutional settings. These validation steps enhanced the credibility and rigor of the findings.

The final stage of the methodology involved synthesizing the themes into a coherent narrative structure that reflects the perspectives of the participants while aligning with the objectives of the research. The analysis did not aim to generalize across all maritime institutions but rather to provide deep, context-rich insights into the ways technical competencies in engine systems can be enhanced through industry-based learning models. By anchoring the research in lived experiences and educational practice, the study delivers a nuanced portrayal of the challenges and opportunities facing maritime vocational education today. Through this methodological approach, the study constructs a meaningful pathway from real-world maritime experiences to educational reform recommendations, capturing voices from both ship and classroom to inform the future of naval engine training in vocational contexts.

3. FINDINGS

The qualitative investigation into enhancing maritime vocational education in naval engine systems yielded several thematic findings derived from the reflective experiences of maritime professionals and vocational lecturers. The collected data, drawn from interviews and focus group discussions, presented clear and cohesive insights into the real conditions of technical education and the competencies required for effective performance in naval engine roles. The participants' accounts revealed critical intersections between industrial practices and educational methods, and uncovered structural gaps that hinder optimal technical competency development in maritime vocational schools.

3.1 Gaps Between Theoretical Instruction and Real-World Engine Room Demands

A prevailing theme that emerged from both professional and lecturer groups was the significant gap between classroom instruction and actual engine room operations. The professionals consistently highlighted that engine-related problems in real-life scenarios rarely occur in controlled, ideal conditions. Instead, they involve unpredictable breakdowns, time-critical decisions, and multi-system interactions under pressure. They emphasized that these complexities are often underrepresented in simulation-based training. Lecturers echoed these concerns, noting that while simulation labs attempt to replicate real engine operations, they fail to capture the operational pressures, unpredictability, and human dynamics of onboard environments. The training modules currently used in maritime vocational schools often prioritize operational procedures in ideal conditions but fall short in preparing students for crisis-based or diagnostic problem-solving in engine failure situations. This disconnect contributes to the insufficient readiness of graduates when entering shipboard service.

3.2 Limited Integration of Industry-Based Learning Models

Both participant groups stressed the lack of structured and sustained industry-based learning within the formal maritime vocational curriculum. Although internships and limited sea-time experiences exist, they are often short-term and observational rather than experiential. Maritime professionals emphasized the need for immersive learning periods where students take active roles in engine room operations under mentorship. Lecturers observed that most students lack opportunities for repetitive practice on real ships, which hinders the internalization of complex engine concepts. They argued for the inclusion of engine room mentoring systems, where cadets could be paired with experienced engineers or mechanics for guided skill development. Such mentorship models, if institutionalized, could significantly close the experiential learning gap.

3.3 Challenges in Curriculum Responsiveness to Technological Change

Participants identified curriculum stagnation as a core barrier to producing competent engine officers. The professionals, particularly those involved in advisory or audit roles, expressed concern that the curricula in many vocational institutions have not kept pace with evolving engine technologies, including automation systems, fuel efficiency management, and digital diagnostics. These elements are becoming standard in modern vessels but are absent or superficially addressed in current teaching practices. Lecturers admitted difficulties in adapting curriculum content due to bureaucratic constraints and a lack of updated teaching materials or engine models. Many relied on legacy instructional content that had limited relevance to the high-tech engines now common in the shipping industry. This disconnect further reinforces the need for dynamic curriculum review processes supported by industry input.

3.4 Underutilization of Seafarers' Experience in Educational Strategy

A critical insight from the professionals was the untapped potential of former seafarers who have transitioned to land-based careers in education or industry management. These individuals carry decades of accumulated operational wisdom, yet their involvement in formal education systems remains minimal. Their knowledge, particularly in engine maintenance, emergency protocols, and interdepartmental coordination, could be translated into case-based learning, storytelling pedagogies, or scenario-based simulations. Lecturers viewed these professionals as valuable resources but noted a lack of structured mechanisms for integrating their input. They suggested formal partnerships between institutions and maritime companies to invite these veterans as guest instructors, curriculum consultants, or field mentors.

3.5 The Need for Competency-Oriented Assessments

Participants uniformly agreed that current assessment systems in vocational maritime education emphasize procedural accuracy over situational awareness or adaptive reasoning. Maritime professionals noted that real engine room competency involves the ability to troubleshoot, communicate effectively with the bridge and technical team, and maintain safety under pressure—skills that are not easily captured through standard written tests or simulations. Lecturers acknowledged this limitation and proposed the inclusion of observational assessments, reflective journals during sea-time, and problem-based practical evaluations. They also emphasized the need for training instructors in assessment design aligned with international maritime competency standards, ensuring that students are evaluated holistically rather than through isolated technical tasks.

3.6 Cultural and Leadership Aspects in Engine Room Education

An unexpected but significant theme was the importance of soft skills and leadership in engine room operations. The professionals recounted instances where interpersonal communication, multicultural collaboration, and ethical decision-making were crucial in avoiding accidents or managing critical incidents. These elements are rarely addressed in technical training but are essential for competent and responsible engine officers. Lecturers acknowledged this gap and expressed interest in integrating leadership and communication training into the technical curriculum. They suggested that engine room drills could incorporate role-play elements, team-based diagnostics, and interdepartmental simulations to foster these non-technical competencies.

4. DISCUSSION

The findings of this research reveal a significant misalignment between the operational expectations of the maritime industry and the pedagogical frameworks employed in maritime vocational institutions, particularly in the field of naval engine systems. Through the experiential narratives of maritime professionals and lecturers, a critical pattern emerges—one that exposes structural limitations, pedagogical

inertia, and institutional disconnects that compromise the development of technically competent engine officers. This discussion explores these themes in depth, critically examining the implications of these findings, correlating them with contemporary challenges in maritime education, and distinguishing the nuanced perspectives of practitioners and educators.

A key insight from this study is the centrality of real-world experience in the development of engine room competencies. While vocational schools have adopted simulation technologies and structured syllabi, these efforts often lack the spontaneity, uncertainty, and system-level problem-solving found in actual engine room scenarios. The professionals interviewed consistently emphasized that no simulation can fully prepare a cadet for the unpredictability of maritime engine operations. This observation aligns with a broader pedagogical concern—experiential learning is not only underutilized, but often inadequately represented within the institutional structure of maritime education. The failure to institutionalize sustained, immersive industry-based learning results in a theoretical competence that does not translate into operational capability.

What distinguishes this research from general discourse on vocational education is the deep integration of dual-domain perspectives—those of industry practitioners and vocational educators. Both groups recognize the gaps between knowledge and application, yet their proposed solutions diverge in instructive ways. The professionals advocate for mentorship and onboard integration, emphasizing informal learning, interpersonal dynamics, and intuitive decision-making cultivated over years at sea. In contrast, the lecturers emphasize curricular reform, assessment redesign, and formal integration of case-based learning. This distinction underscores a critical pedagogical tension: the maritime classroom tends to prioritize structure and predictability, while the maritime workplace demands adaptability and resilience.

Moreover, the discussion around outdated curricula highlights the inertia that persists in many vocational institutions. While engine systems aboard modern ships evolve rapidly—integrating automation, emissions control, and digital diagnostics—teaching materials often remain anchored in past technologies. This mismatch compromises the readiness of graduates, who find themselves unprepared for tasks involving software-driven monitoring systems, sustainable fuel operations, or electronic troubleshooting. Such technological dissonance is not merely a curriculum issue, but a strategic failure to anticipate the future of maritime engineering. It raises broader questions about institutional agility, access to updated technology, and the channels through which industry trends are communicated to academic environments.

Another significant theme is the untapped value of maritime professionals as pedagogical contributors. The findings suggest that the transition of seafarers into educational advisory roles remains ad hoc and informal. These individuals carry operational knowledge that is context-rich, tested in crisis, and often embedded in lived experience. Yet, institutional reluctance, lack of structured pathways, and administrative barriers limit their integration into formal education. This research challenges such exclusion, advocating for a more inclusive and adaptive educational ecosystem where professional experience is treated not as peripheral, but central to technical instruction.

This discussion also brings to the fore the issue of competency measurement. Current assessment mechanisms, heavily dependent on written and procedural testing, are inadequate for evaluating the holistic readiness of cadets. The professionals' emphasis on non-technical skills—communication, leadership, ethical decision-making—underscores the multifaceted nature of engine room work. The suggestion by lecturers to include reflective journals, problem-based evaluations, and observational assessments opens up a new dimension of pedagogical practice, one that values both technical accuracy and adaptive behavior. Here, the convergence of practitioner expectations and lecturer innovations presents a pathway for more comprehensive and competency-aligned assessment models.

Furthermore, the discussion surfaces the often-overlooked sociocultural dimensions of engine room operations. Maritime professionals referenced not only mechanical tasks but also the interpersonal, multicultural, and ethical challenges inherent in shipboard life. These elements, though frequently invisible in syllabi, are critical for operational safety and team effectiveness. The inclusion of leadership development, scenario-based role play, and interdepartmental simulations could offer meaningful pedagogical interventions to address this gap. Such an expansion of the curriculum would not only enhance technical proficiency but also foster the human competencies required in modern maritime workplaces.

In comparing the perspectives of professionals and lecturers, it becomes evident that while both groups acknowledge the same educational shortcomings, their positional experiences influence their strategic orientations. Professionals, shaped by years of sea-based leadership, often see education through the lens of risk, responsibility, and real-time consequence. Lecturers, shaped by institutional limitations and

pedagogical logic, approach reform through structure, planning, and measurable outcomes. This divergence, however, is not a contradiction, but a complementary dynamic that, if harnessed properly, can lead to transformative educational models. By bridging these perspectives, the research invites a hybrid approach—one that combines structured curriculum reform with organic, field-based mentorship.

The discussion underscores that enhancing maritime vocational education in naval engine systems is not a matter of marginal adjustments, but of foundational rethinking. It requires a shift from knowledge transmission to competency cultivation, from isolated simulations to integrated field immersion, and from top-down curriculum design to co-constructed learning environments informed by operational realities. This reconceptualization is vital not only for producing competent graduates but for sustaining the relevance and resilience of maritime education in a world increasingly shaped by environmental imperatives, technological transformation, and globalized workforce demands.

5. CONCLUSION

This research critically explored the enhancement of technical competency in maritime vocational education, specifically in naval engine systems, through qualitative insights from maritime professionals and vocational lecturers. The findings revealed a significant gap between theoretical instruction and real-world engine room demands, highlighting the urgency for curriculum reform and the integration of industry-based learning. Maritime professionals emphasized the irreplaceable value of experiential learning gained from years at sea, while lecturers pointed to institutional constraints and the need for more dynamic, practice-oriented teaching strategies. The study concludes that effective competency development in naval engine systems cannot be achieved through simulation and theory alone. A shift toward immersive, mentorship-based learning that incorporates authentic engine room challenges is essential. Furthermore, updated curricula aligned with modern technological advancements, along with competency-based assessment models, are crucial to prepare cadets for the realities of maritime operations. Both practitioner and educator perspectives, while distinct, offer complementary solutions that, when integrated, can transform maritime vocational training into a more responsive and resilient educational model. By bridging institutional education with operational realities, this research contributes a strategic foundation for enhancing maritime technical training. It offers a path toward producing graduates who are not only technically proficient but also adaptable, safety-conscious, and ready to meet the evolving demands of the maritime industry.

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