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AN INDUSTRY-INTEGRATED LEARNING MODEL FOR MARITIME VOCATIONAL EDUCATION: DEVELOPMENT AND EVALUATION THROUGH INDUSTRIAL WORKFLOWS AND SIMULATOR-BASED LEARNING

Wegig Pratama [1], Suhono Suhono [2], Bambang Sudarsono [3], Muhammad Amin [4]*
[1] Sekolah Tinggi Maritim, Yogyakarta, Indonesia
[2] Universitas Ma'arif Lampung, Lampung, Indonesia
[3] Universitas Ahmad Dahlan, Yogyakarta, Indonesia
[4] Universitas Negeri Medan, North Sumatera, Indonesia
Correspondence Author: wegigpratama@gmail.com

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Abstract : *The gap between Maritime Vocational Education (MVE) and shipping industry demands has resulted in graduates with technical skills but limited workplace readiness. This study developed and evaluated an Industry-Integrated Learning Model (IILM) that integrates industrial workflows, authentic operational scenarios, behavioral assessment, and reflective debriefing into simulator-based learning. Unlike conventional simulator-based approaches that mainly focus on technical performance, IILM embeds industry practices within the learning process to strengthen work readiness. The study employed a modified ADDIE-based Research and Development (R&D) approach involving 60 Nautical Studies students. Data were collected through expert validation, bridge simulator assessment, and the Work Readiness Assessment Rubric (WRAR). The model achieved high feasibility (M = 4.62/5.00), and the experimental group obtained significantly higher post-test scores (M = 84.67) than the control group (M = 71.33, p < 0.001). The findings demonstrate that IILM improves students' work readiness, particularly in situational awareness and collaborative communication.*

Keywords : *Maritime Vocational Education; Industry-Integrated Learning Model; Work Readiness.*

Abstrak : *Kesenjangan antara Pendidikan Vokasi Maritim (MVE) dan tuntutan industri pelayaran telah menyebabkan lulusan memiliki keterampilan teknis, tetapi masih memiliki keterbatasan dalam kesiapan kerja. Penelitian ini mengembangkan dan mengevaluasi Industry-Integrated Learning Model (IILM) yang mengintegrasikan alur kerja industri, skenario operasional autentik, asesmen kompetensi perilaku, dan reflective debriefing ke dalam pembelajaran berbasis simulator. Berbeda dengan pendekatan pembelajaran berbasis simulator konvensional yang lebih berfokus pada kinerja teknis, IILM menempatkan praktik industri sebagai bagian integral dalam proses pembelajaran untuk memperkuat kesiapan kerja mahasiswa. Penelitian ini menggunakan pendekatan Research and Development (R&D) berbasis model ADDIE yang dimodifikasi dengan melibatkan 60 mahasiswa Program Studi Nautika. Data dikumpulkan melalui validasi ahli, asesmen kinerja menggunakan bridge simulator, dan Work Readiness Assessment Rubric (WRAR). Model yang dikembangkan memperoleh tingkat kelayakan tinggi (M = 4,62/5,00), dan kelompok eksperimen memperoleh skor pascates yang secara signifikan lebih tinggi (M = 84,67) dibandingkan kelompok kontrol (M = 71,33; p < 0,001). Hasil penelitian menunjukkan bahwa IILM mampu meningkatkan kesiapan kerja mahasiswa, khususnya pada aspek kesadaran situasional dan komunikasi kolaboratif.*

Kata Kunci : *Pendidikan Vokasi Maritim; Industry-Integrated Learning Model; Kesiapan Kerja.*

INTRODUCTION

The maritime industry plays a significant role in global transportation and trade, accounting for a large proportion of international cargo movement and requiring a workforce capable of adapting to technological developments, digitalization, and evolving operational standards (Alop, 2023). The transformation of maritime operations has increased the demand for graduates who possess not only technical competencies but also workplace-oriented capabilities, including situational awareness, communication skills, teamwork, and adaptive decision-making (Gekara & Nguyen, 2022; Radhakrishnan, 2024). Therefore, Maritime Vocational Education (MVE) institutions are expected to provide learning experiences that enable students to develop competencies aligned with the complexity of contemporary maritime workplaces.

However, a persistent challenge remains in bridging the gap between vocational education outcomes and industry expectations. Previous studies have reported that many maritime graduates demonstrate adequate technical knowledge and certification but still experience difficulties in applying their competencies within authentic operational environments (Bhaskar et al., 2023; Rohmah, 2026). This condition occurs because many learning activities remain dominated by procedural training and technical performance, providing limited opportunities for students to engage with workplace decision-making, collaborative responsibilities, and uncertain operational situations (Lighthall, 2022; Raza et al., 2024). As a result, improving maritime graduate readiness requires learning approaches that integrate technical capability with cognitive, behavioral, and professional competencies.

Several approaches have been developed to strengthen the relationship between vocational education and industry requirements, including Work-Integrated Learning (WIL), work-based learning, Teaching Factory, project-based learning, and industry partnership models. These approaches have contributed to improving the authenticity and relevance of vocational learning by connecting students with professional practices (Autsadee & Phanphichit, 2025). Nevertheless, existing approaches still present several limitations. WIL and industry partnership models commonly emphasize workplace exposure, internships, or collaboration with external stakeholders, while industry practices are not always embedded within the core instructional process (Chen & Lin, 2022). Similarly, project-based and authentic learning approaches encourage problem-solving and experiential engagement but do not always provide structured mechanisms for integrating industrial workflows, professional performance standards, and behavioral competency assessment within learning activities (Mallam et al., 2022).

Simulator-based learning has also become an important approach in maritime education because it provides realistic environments for practicing operational procedures and technical competencies. Previous studies indicate that simulator technology can improve training effectiveness and provide opportunities for learners to experience complex operational situations (Emad et al., 2025; Praetorius et al., 2023). However, simulator-based instruction is frequently implemented primarily for procedural compliance and technical assessment, while the development of communication, teamwork, adaptive decision-making, and reflective professional judgment remains insufficiently integrated (Autsadee & Phanphichit, 2025; Pratama et al., 2026). Therefore, existing approaches tend to address industry exposure, simulation practice, and competency assessment as separate components rather than as interconnected elements within a comprehensive instructional framework.

The development of an integrated learning model requires a strong theoretical foundation. From the perspective of experiential learning, professional competence develops through meaningful cycles of experience, reflection, conceptual understanding, and application in authentic situations. Therefore, learning environments that simulate workplace conditions can support the development of professional capability by allowing learners to connect practical experiences with reflective processes (Manuel, 2021). Situated learning theory further explains that knowledge and competence are constructed through participation in authentic social and professional contexts, suggesting that vocational learning becomes more effective when students engage in activities that resemble real occupational practices (Billett, 2021). In addition, work-based learning perspectives emphasize that industry relevance can be strengthened when educational activities incorporate authentic tasks, workplace expectations, and competency-based evaluation mechanisms (Sampson et al., 2023).

Despite these theoretical and practical developments, a research gap remains. Existing learning approaches have not fully addressed how industry practices can be systematically embedded into simulator-supported learning environments to develop both technical and workplace competencies simultaneously. Limited attention has been given to instructional models that integrate industrial workflows, authentic operational scenarios, behavioural competency assessment, and reflective debriefing as interconnected components within a single pedagogical framework. Therefore, further development is required to establish a model that positions industry practices not merely as external collaboration mechanisms but as an integral part of instructional design, implementation, and evaluation.

To address this gap, this study develops the industry-Integrated Learning Model (IILM) for Maritime Vocational Education. Unlike conventional work-based learning models that primarily emphasize workplace exposure, project-based learning models that focus on task completion, or simulator-based learning models that mainly emphasize technical execution, IILM integrates industrial workflows, authentic operational scenarios, collaborative performance assessment, and structured reflective debriefing into a unified learning framework. The novelty of IILM lies in transforming industry involvement from an external partnership approach into an embedded instructional mechanism that connects workplace practices with simulator-based experiential learning.

Based on the identified research gap and theoretical foundation, this study aims to develop, validate, and evaluate the effectiveness of the industry-Integrated Learning Model for Maritime Vocational Education. Specifically, this study examines whether the implementation of IILM can improve students' work readiness, particularly in situational awareness, collaborative communication, and operational performance.

METHOD

This study employed a Research and Development (R&D) design using a modified ADDIE framework to develop and evaluate the industry-Integrated Learning Model (IILM) for Maritime Vocational Education. The R&D approach was selected because the objective of this study was not only to examine the effect of an instructional intervention but also to systematically develop, validate, revise, and evaluate a new learning model based on identified educational and industry needs. The modified ADDIE framework in this study consisted of five interconnected stages: analysis, design, development, implementation, and evaluation. Each stage involved a systematic process of needs identification, model formulation, expert review, refinement, and empirical evaluation (Branch & Kopcha, 2021).

During the analysis stage, data were collected from maritime competency requirements, existing simulator-based learning practices, and workplace expectations to identify the gap between vocational learning outcomes and industry demands. These findings informed the initial design of IILM. The design stage involved the development of the conceptual framework, instructional syntax, learning scenarios, and assessment procedures. The initial model was structured around four main components: industrial workflow integration, authentic operational scenarios, behavioural competency assessment, and reflective debriefing.

In the development stage, the initial prototype was reviewed by maritime education experts and industry practitioners. The validation process focused on the relevance of learning components, alignment with maritime operational practices, assessment indicators, and feasibility of implementation. Based on expert feedback, iterative revisions were conducted to improve scenario design, assessment criteria, and instructional procedures. The revised model was then implemented in a maritime vocational learning context. The implementation stage functioned as a field trial to examine the practicality and effectiveness of the developed model through simulator-based learning activities. Two cycles of refinement were conducted: the first revision focused on learning syntax and scenario alignment, while the second revision focused on assessment indicators and implementation procedures before field testing. The evaluation stage examined the effectiveness of IILM using comparative analysis between students who received IILM-based instruction and those who received conventional simulator-based learning.

The study involved 60 Nautical Studies students who participated in simulator-based learning activities. Participants were divided into an experimental group and a control group. The experimental group received instruction using the developed IILM framework, while the control group received conventional simulator-based instruction. Data collection involved three instruments: expert validation sheets, simulator-based performance assessment, and the Work Readiness Assessment Rubric (WRAR). The expert validation instrument was used to evaluate the feasibility of the developed model, while WRAR was used to measure work readiness dimensions including technical execution, situational awareness, and collaborative communication.

Descriptive analysis was conducted to summarize expert validation results and participant performance. Inferential statistical analysis included independent-samples t-tests and ANCOVA to examine differences between groups while controlling for pre-test scores. Effect size analysis using Cohen's d was conducted to determine the practical magnitude of differences between groups.

RESULT AND DISCUSSION

1. Results

a) Development Process and Expert Validation of the Industry-Integrated Learning Model

The development of the Industry-Integrated Learning Model (IILM) was conducted using a modified ADDIE-based Research and Development (R&D) approach consisting of analysis, design, development, implementation, and evaluation stages. During the analysis stage, the researchers identified maritime workplace competency requirements, existing simulator-based learning practices, and limitations in current instructional approaches. These findings were used as the basis for developing the initial IILM framework.

The development process resulted in three main instructional products: 1) the Industry-Integrated Learning Model Handbook, containing the conceptual framework, implementation procedures, and learning syntax; 2) Scenario-Based Simulator Learning Guides, translating authentic industrial workflows into structured simulator activities; and 3) the Work Readiness Assessment Rubric (WRAR), used to assess students' work readiness dimensions.

The initial model consisted of four main instructional components: industrial workflow integration, authentic operational scenarios, behavioural competency assessment, and reflective debriefing. These components were organized into five sequential learning phases: industry orientation, scenario planning, simulator-based operational execution, collaborative crisis management, and reflective debriefing and performance evaluation.

Before implementation, the developed model was reviewed by three maritime education experts and two active Master Mariners. The validation process evaluated the relevance of industry workflow integration, learning syntax, assessment procedures, and reflective debriefing mechanisms. Based on expert recommendations, revisions were conducted regarding scenario alignment, assessment indicators, and the sequence of learning activities. The final validation results are presented in Table 1.

Table 1: Expert Validation Results of the Industry-Integrated Learning Model

Component Evaluated	Mean Score
Industry Workflow Integration	4.80
Learning Syntax	4.56
Assessment Rubric (WRAR)	4.61
Reflective Debriefing Process	4.49
Overall Mean	4.62

The developed model achieved an overall feasibility score of M = 4.62/5.00. The highest evaluation score was obtained for industry workflow integration (M = 4.80), followed by the assessment rubric (M = 4.61), learning syntax (M = 4.56), and reflective debriefing process (M = 4.49).

To examine the comparability of the groups before intervention, an independent-samples t-test was conducted using pre-test scores from 60 Nautical Studies students. The experimental group (n = 30) obtained a mean score of 62.40 (SD = 5.12), while the control group (n = 30) obtained a mean score of 61.87 (SD = 4.95).

The analysis showed no statistically significant difference between groups before the intervention, $t(58) = 0.41$, $p = 0.684$. These results indicate that both groups had comparable initial work readiness scores before the learning intervention.

b) Post-test Results, Comparative Analysis, and ANCOVA Analysis

After an eight-week intervention, both groups completed a post-test involving an unscripted maritime crisis scenario consisting of simultaneous steering failure and heavy traffic conditions. The experimental group that received instruction using IILM obtained a mean post-test score of 84.67 (SD = 4.26), while the control group achieved a mean score of 71.33 (SD = 5.82). An independent-samples t-test indicated a statistically significant difference between the groups, $t(58) = 10.12$, $p < 0.001$. The effect size analysis showed Cohen's $d = 2.61$, indicating a large difference between the two groups.

The comparison of work readiness dimensions measured using WRAR is presented in Table 2.

Table 2: Comparison of Post-test Work Readiness Dimensions between Groups

Competency Dimension	Control Group Mean	Experimental Group Mean	t-value	p-value
Technical Watchkeeping Execution	29.03	28.67	0.35	0.728
Situational Awareness and Risk Assessment	21.40	28.20	8.94	<0.001
Collaborative Team Communication	20.90	27.80	9.11	<0.001

The results indicate statistically significant differences in situational awareness and collaborative team communication between groups. However, technical watchkeeping execution did not show a significant difference ($p = 0.728$). The observed pattern shows that both groups achieved similar performance in procedural technical execution, while differences were identified in competency dimensions related to interpreting operational situations, responding to complex conditions, and coordinating with team members.

To further examine the intervention effect while controlling for pre-test scores, ANCOVA analysis was conducted. The results showed a statistically significant effect of the learning model on post-test work readiness scores after controlling for baseline differences, $F(1, 57) = 96.48$, $p < 0.001$. The statistical results demonstrate that students who participated in IILM-based learning achieved significantly different work readiness outcomes compared with students who received conventional simulator-based instruction within the context of this study. Thus, the findings provide empirical evidence regarding the feasibility, implementation, and effectiveness evaluation of the Industry-Integrated Learning Model in Maritime Vocational Education.

2. Discussion

The findings of this study indicate that the Industry-Integrated Learning Model positively contributes to students' work readiness in Maritime Vocational Education. Students who participated in the model achieved higher performance than those who received conventional simulator-based instruction, particularly in situational awareness and collaborative communication. These findings suggest that learning experiences designed around authentic workplace conditions can strengthen competencies required in contemporary maritime operations. This result supports the argument that vocational education becomes more meaningful when learning activities are aligned with workplace expectations and professional practice (Asonitou, 2025).

The absence of significant differences between the experimental and control groups before the intervention indicates that both groups possessed comparable initial competencies. However, substantial differences emerged after the implementation of the model. Because both groups used simulator-based learning environments, the improvement cannot be attributed solely to simulator technology (Sudarsono et al., 2025). Instead, the findings suggest that the integration of industrial workflows, workplace decision-making processes, and collaborative operational responsibilities within the instructional design played a critical role in enhancing learning outcomes. This interpretation aligns with recent evidence that academic learning must connect to workplace realities, as checklist-based instruction falls short of developing adaptive operational competence (Weng et al., 2024).

One of the most significant findings concerns the improvement in situational awareness. Maritime operations are characterized by uncertainty, time pressure, and continuously changing environmental conditions (Sudarsono et al., 2024). In such contexts, personnel must interpret information accurately, recognize potential risks, and anticipate the consequences of their decisions. The superior performance demonstrated by students in the experimental group suggests that the Industry-Integrated Learning Model supported the development of these capabilities beyond the level achieved through conventional instruction (Kim & Sim, 2023).

This finding can be explained through the perspective of situated learning, which proposes that knowledge is more effectively developed when learning occurs within contexts that resemble authentic professional practice. In the present study, students were exposed to industry-derived operational scenarios that required them to evaluate information, identify hazards, and make decisions in dynamic situations. Rather than merely following procedural instructions, students were expected to understand the operational context and respond appropriately to emerging conditions. As a result, learning extended beyond technical compliance and fostered adaptive decision-making abilities. This interpretation is consistent with previous studies showing that situational awareness and cognitive flexibility are fundamental components of safe maritime performance (Billett, 2021; Chae, 2022). It also supports the argument that authentic learning experiences contribute to the development of adaptive competence in safety-critical occupations.

The effectiveness of the model was particularly evident in situations requiring adaptive responses. During simulator activities, students encountered operational disruptions, competing priorities, and complex decision-making demands. These situations closely resemble the challenges encountered in actual maritime workplaces (Chao et al., 2024). Repeated engagement in such scenarios may have strengthened students' ability to interpret environmental cues, evaluate alternatives, and adjust their actions in response to changing circumstances. Therefore, the improvement in situational awareness appears to result not only from increased practice but also from the authentic and contextualized nature of the learning experiences provided by the model (Gros & Lopez, 2021; Hovden et al., 2023).

Another important finding concerns collaborative communication. Communication plays a critical role in maritime operations because effective performance depends on coordination among crew members. During emergency situations, communication failures can lead to delayed responses, misunderstandings, and operational errors. Students who participated in the Industry-Integrated Learning Model demonstrated stronger communication performance than those who received conventional instruction. This finding is consistent with Özdemir and Erden (2022), who identified communication and coordination as essential behavioral competencies in maritime crisis situations. It also supports the recommendation of Renganathan et al. (2021) that communication skills should be explicitly integrated into simulator-based learning and assessment (Özdemir & Erden, 2022; Renganathan et al., 2021).

The exceptionally large effect size observed in this study (Cohen's $d = 2.61$) deserves further consideration. Such a substantial effect may be associated with the considerable differences in learning experiences provided to the experimental group.

Students exposed to the Industry-Integrated Learning Model engaged not only in simulator-based practice but also in industrial workflow analysis, collaborative crisis-management activities, behavioral performance assessment, and structured reflective debriefing. The combined influence of these instructional elements likely produced cumulative learning gains that exceeded those typically observed in conventional simulator-based instruction. Consequently, the effect size should be interpreted as reflecting the integrated nature of the intervention rather than the influence of a single instructional component (Pundhir et al., 2023).

The improvement in collaborative communication may be explained by the instructional structure of the model. Conventional simulator training often emphasizes individual procedural performance and technical accuracy. In contrast, the Industry-Integrated Learning Model positions communication as an integral part of task completion. Students were required to exchange information, coordinate responsibilities, confirm decisions, and respond collectively to operational challenges. Consequently, communication became a necessary component of successful performance rather than a supplementary activity (Santhanam et al., 2022).

From a social constructivist perspective, learning occurs through interaction and participation in shared activities. Professional competence develops when learners collaborate, negotiate meaning, and construct shared understanding. The collaborative scenarios implemented in this study created opportunities for students to engage in communication practices that closely resembled those used in professional maritime settings (Srinivasan & Kumar, 2022). Through repeated participation in team-based activities, students may have internalized effective communication strategies and developed greater confidence in coordinating with others during operational tasks. Therefore, the observed improvement reflects not only enhanced interpersonal communication but also the development of collective operational competence.

The positive outcomes observed in this study may also be attributed to the integration of industry workflows into learning activities. Conventional simulator-based instruction frequently focuses on procedural compliance and technical execution. Although these competencies remain important, workplace performance often requires individuals to integrate technical, cognitive, and interpersonal skills simultaneously. The Industry-Integrated Learning Model was specifically designed to address this requirement by embedding authentic industrial workflows within simulator-based instruction (Pratama et al., 2026). Students were required to analyze operational situations, evaluate risks, coordinate actions, and justify decisions while performing technical tasks. Such learning experiences are consistent with authentic vocational learning principles that emphasize the alignment of educational activities with workplace practices (Billett, 2021). Furthermore, realistic simulator environments function as professional learning spaces that allow students to develop occupational competencies before entering the workforce (Kyndt et al., 2023).

Another factor contributing to the effectiveness of the model is the inclusion of structured debriefing sessions. Debriefing encouraged students to reflect on their actions, evaluate alternative responses, and identify areas for improvement. Reflection is widely recognized as a critical mechanism through which experience is transformed into professional knowledge. In this study, reflective discussions enabled students to connect operational experiences with workplace expectations and professional standards. Previous studies have demonstrated that reflective learning improves professional judgment and supports long-term learning outcomes in high-risk occupations (Gros & Lopez, 2021). Similarly, debriefing activities that resemble professional safety investigations can strengthen students' understanding of operational decision making and safety culture in maritime education (Molloy et al., 2024; Srinivasan & Kumar, 2022).

The findings also highlight the importance of strengthening collaboration between vocational institutions and industry stakeholders. As the maritime sector continues to adopt digital technologies, automation, and new operational standards, educational institutions must ensure that learning experiences remain relevant to workplace needs (Pundhir et al., 2023). The results of this study suggest that industry involvement becomes more effective when it is embedded directly within learning design, implementation, and assessment rather than limited to curriculum consultation or internship programs. Such collaboration can improve curriculum relevance, competency assessment, and the authenticity of learning experiences. This argument supports the position of Chae (2022), who emphasized the importance of shared evaluation frameworks between educational institutions and industry, and Chao et al. (2024), who highlighted the value of stronger industry participation in addressing workforce development challenges (Chae, 2022; Chao et al., 2024).

Although the findings are encouraging, several limitations should be acknowledged. The study involved a relatively small sample and was conducted within a specific maritime educational context. Differences in institutional resources, curriculum structures, and instructional practices may influence the effectiveness of the model in other settings. Therefore, further studies involving larger samples and multiple institutions are required to examine the generalizability of the findings.

Overall, the findings suggest that the Industry-Integrated Learning Model strengthens the alignment between vocational education and workplace requirements by integrating authentic workplace experiences, collaborative problem solving, and reflective performance evaluation within a single instructional framework. The effectiveness of the model appears to result from the interaction of these complementary mechanisms, which collectively create learning conditions that resemble the cognitive, behavioral, and social demands of contemporary maritime operations. Consistent with Tang and Chow (2025), vocational learning models that incorporate workplace input and behavioral performance assessment offer promising opportunities for improving graduate preparedness (Tang & Chow, 2025). Therefore, the model developed in this study provides a practical and theoretical contribution to the advancement of work-readiness-oriented learning in Maritime Vocational Education.

CONCLUSION

This study developed and evaluated the Industry-Integrated Learning Model (IILM) for Maritime Vocational Education. The findings indicate that the developed model achieved high feasibility and resulted in improved work readiness outcomes, particularly in situational awareness and collaborative communication, while technical watchkeeping performance showed no significant difference between groups. The theoretical contribution of this study is the reconceptualization of industry integration as an embedded learning mechanism rather than merely an external partnership approach. Unlike conventional work-based learning, project-based learning, and simulator-based training models, IILM integrates industrial workflows, authentic operational scenarios, behavioral competency assessment, and reflective debriefing into a unified instructional framework. Practically, IILM provides guidance for curriculum developers, maritime training institutions, and industry stakeholders to design learning environments that better align vocational education with workplace requirements through authentic scenarios, competency-based assessment, and industry collaboration.

This study is limited by its relatively small sample size, single institutional context, quasi-experimental design, and short-term evaluation of learning outcomes, which restrict broader generalization. Future research should examine IILM implementation across diverse maritime institutions using larger samples, longitudinal designs, and workplace-based evaluations to determine the sustainability of competency development and the contribution of individual model components.

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