An Optimized Ship Engine Room Simulator Configuration for an Effective Engine Room Resource Management Training

Ismail Cicek [1, *] and Burak Cavusoglu [1]

[1] *Istanbul Technical University, Maritime Faculty, Marine Engineering Department, Türkiye*

[*] *Corresponding author: cicekism@itu.edu.tr; Tel.: +90-535-515-3030.*

Abstract: Effective teamwork is crucial for safety and operational success in shipping operations. However, the absence of a unified model course in Engine Room Resource Management (ERM) training leads to a variety of instructional approaches. While Maritime Education and Training (MET) institutions typically achieve the objectives of ERM training through a combination of multiple courses within their curricula, institutions dedicated to ERM training need guidance on integrating these model courses into a concise and effective training regimen using an engine room simulator (ERS).

This study presents a proposed optimized system configuration for an effective ERM training program. The proposed ERS model integrates the IMO Model Course 2.07 and the competencies outlined in the Standards of Training, Certification, and Watchkeeping (STCW). By leveraging ERS, the model optimizes training hours while maintaining instructional efficacy. The optimized system configuration ensures compliance with STCW 2010 requirements by emphasizing collaborative teamwork, leadership, and communication skills. It facilitates the creation of practical scenarios replicating real-world challenges, enhancing decision-making capabilities. The study details the development and application of this optimized configuration through diverse training scenarios demonstrated with ERS and pilot studies with various setups. Importantly, the model is designed to be adaptable for implementation by different institutions, thereby broadening its potential impact. This research contributes to advancing ERM training, aligning with regulatory standards, and fostering a culture of effective teamwork.

Keywords: Engine Room Simulators, Maritime Education and Training, Teamwork, Collaborative Teamwork, Configuration Optimization

1. Introduction

A vessel's safe and efficient operation hinges on its crew's coordinated efforts, particularly within the engine room. Engine room personnel face a dynamic environment where effective teamwork is paramount for handling complex machinery, troubleshooting malfunctions, and responding to emergencies. Clear communication, strong leadership, and collaborative decision-making are crucial for ensuring smooth engine room operations and mitigating potential risks [1].

Engine Room Resource Management (ERM) training equips maritime professionals with the necessary skills to navigate these challenges [2]. International Maritime Organization (IMO) regulations, specifically the Standards of Training, Certification, and Watchkeeping (STCW) convention, mandate ERM training for all engine room officers. However, no standardized model course within the IMO framework is dedicated solely to ERM.

This lack of a standardized approach leads to a varied landscape of ERM training programs offered by Maritime Education and Training (MET) institutions. Institutions often integrate elements from IMO Model Course 2.07, which provides a general framework for ERM training, into various courses spread across the curriculum. This fragmented approach can lead to inefficiencies in training delivery and may not adequately address all the critical STCW competencies required for effective engine room operations.

Practical ERM training is essential for ensuring safety, efficiency, and environmental responsibility in maritime operations. However, challenges in ERM training implementation need to be addressed to optimize its effectiveness. These challenges include the lack of standardization in ERM training courses, the integration of ERM principles across various courses within MET curricula, concerns regarding training efficiency, and the need for practical skill development for real-world engine room scenarios [2].

The absence of a standardized International Maritime Organization (IMO) model course for ERM training leads to diverse approaches by MET institutions, potentially resulting in fragmented training programs that may not comprehensively cover all essential skills required for effective engine room operations. Moreover, the dispersion of ERM elements across multiple courses within the MET curriculum can hinder students' understanding of the interconnectedness of ERM principles, impeding the development of a holistic comprehension of ERM [3]. The current fragmented approach to ERM training may also raise concerns about training redundancy and extended training durations, affecting the overall efficiency of training programs [4].

Furthermore, traditional lecture-based training methods may not adequately equip trainees with the practical skills for effective teamwork and decision-making in real-world engine room scenarios, highlighting the need for more hands-on and scenario-based training approaches. Addressing these challenges is crucial to enhance the effectiveness of ERM training and better prepare future maritime professionals for the complexities of engine room operations.

The challenges in ERM training implementation are vital for ensuring a well-functioning, safe, and environmentally responsible engine room operation. By addressing issues related to standardization, curriculum integration, training efficiency, and practical skill development, the maritime industry can enhance the impact of ERM training on operational safety and efficiency. The references cited provide insights into enterprise risk management practices, challenges, and strategies for success, offering valuable perspectives on addressing obstacles in ERM implementation across various industries.

2. Literature Review

2.1 Overview of Engine Room Resource Management Training

ERM training plays a vital role in equipping maritime professionals with the necessary skills to navigate the complexities of the engine room environment. ERM training emphasizes non-technical skills such as communication, teamwork, decision-making, situational awareness, and leadership, which are crucial for ensuring safe, efficient, and environmentally responsible engine room operations [2]. The IMO mandates ERM training for all engine room officers through the STCW convention. IMO Model Course 2.07 provides a general ERM training framework outlining the required core competencies [1]. However, no standardized model course is dedicated solely to ERM within the IMO framework.

This lack of standardization has led to a diverse landscape of ERM training programs offered by MET institutions. Institutions often adopt a fragmented approach, integrating elements from IMO Model Course 2.07 into various courses spread throughout the curriculum [3]. This approach can lead to inefficiencies and may not effectively cover all the critical STCW competencies required for engine room operations [4]. Effective teamwork, including engine room resource management, ensures maritime operations' safety, efficiency, and success. This subsection explores the critical significance of teamwork and collaborative training in the maritime industry:

Enhanced Situational Awareness: Teamwork fosters a shared understanding of the operational environment and situational awareness among crew members. By collaboratively monitoring vessel systems, communicating observations, and exchanging critical information, crew members can collectively identify potential risks, anticipate challenges, and respond proactively to emergent situations in real time [2].

Improved Decision-Making: Collaborative training promotes collective decision-making processes, enhancing multiple perspectives and expertise to arrive at informed and effective decisions. By engaging in open dialogue, soliciting input from diverse team members, and considering alternative courses of action, maritime professionals can make more robust decisions under uncertainty and time constraints, mitigating risks and optimizing operational outcomes [7].

Effective Communication: Clear and effective communication is the cornerstone of successful teamwork in maritime operations. Collaborative training programs emphasize developing communication skills, including active listening, concise articulation, and assertive expression, to facilitate seamless information exchange and coordination among crew members. By fostering a culture of open communication and mutual respect, collaborative training enhances crew coordination, task allocation, and error detection in high-stakes environments [8].

Resilience to Challenges and Emergencies: Teamwork equips maritime professionals with the resilience and adaptability to navigate unforeseen challenges and emergencies effectively. Through collaborative training exercises, such as scenario-based simulations and tabletop drills, crew members can practice coordinated responses to various contingencies, including equipment failures, adverse weather conditions, and onboard emergencies. By rehearsing roles, responsibilities, and communication protocols in a controlled setting, teams can enhance their preparedness and confidence in handling real-world crises [9].

Cultivation of Team Cohesion and Trust: Collaborative training fosters the development of team cohesion, trust, and mutual reliance among crew members. By engaging in shared experiences, overcoming challenges together, and celebrating successes as a team, maritime professionals build strong interpersonal relationships and a sense of camaraderie that underpins effective teamwork. This cohesion enhances crew morale, motivation, and performance, ultimately contributing to a positive safety culture and operational excellence [10].

Research by [11] highlights the concerns regarding the effectiveness of current ERM training practices, which are:

- Lack of standardization in training content and delivery methods.
- Fragmented integration of ERM principles across the curriculum.
- Limited focus on practical skill development for real-world scenarios.
- Inefficiencies in training delivery, potentially leading to extended training durations.

These limitations in ERM training hinder its ability to fully prepare future maritime professionals for the challenges of the engine room. The following section will delve deeper into specific challenges and gaps in ERM training identified within the literature.

The current landscape of ERM training reflects the absence of a single standardized model course within the IMO framework. This section explores the various existing models and approaches MET institutions use.

2.2 Existing ERM Training Models and Approaches

IMO Model Course 2.07 can be integrated in a fragmented manner. A common approach involves integrating IMO Model Course 2.07 elements into existing MET curriculum courses [3]. This approach offers flexibility but can lead to fragmentation, as ERM principles are dispersed across various subjects. This fragmentation may hinder students' ability to develop a holistic understanding of ERM and its interconnectedness [11]. Our research indicates that existing ERM training methods are realized in the following training types:

Standalone ERM Courses: Some institutions offer dedicated ERM courses that aim to comprehensively cover the STCW competencies outlined in Model Course 2.07 [2]. However, these standalone courses can be time-consuming and may lead to curriculum overload, impacting the overall efficiency of training programs [4].

Traditional Lecture-Based Training: ERM programs often use Traditional lecture-based training methods. While these methods can effectively convey theoretical knowledge, they may fail to equip trainees with the practical skills required for real-world engine room scenarios. Effective teamwork and decision-making often rely on applying theoretical knowledge in dynamic and time-sensitive situations [10].

Limitation of Existing Approaches: ERM training models and approaches face several limitations. The fragmented integration of Model Course 2.07 can lead to knowledge gaps and hinder a holistic understanding of ERM. Standalone courses can be time-consuming, while traditional lecture-based methods may lack a focus on practical skill development. These limitations highlight the need for innovative approaches that address the identified gaps and enhance the effectiveness of ERM training for future maritime professionals [12].

2.3 Critique of Current ERM Training Methods

While aiming to equip maritime professionals with essential skills, the current landscape of ERM training faces limitations that hinder its effectiveness. Here's a closer look at the critical areas for critique:

Fragmented Approach:

Knowledge Gaps and Incoherent Understanding: Fragmenting ERM principles across various courses can lead to knowledge gaps and hinder students' ability to develop a holistic understanding of ERM. The interconnectedness of ERM concepts may not be readily apparent, limiting the ability to apply them effectively in real-world scenarios [11].

Difficulty Connecting Theory to Practice: Disseminating ERM knowledge through various subjects might make it challenging for students to connect theoretical concepts with practical applications in the engine room. This disconnect can hinder the development of essential skills for real-world problem-solving [3].

Standalone Courses:

Time Constraints and Curriculum Overload: While comprehensive, standalone ERM courses can be time-consuming to complete. This can lead to curriculum overload, potentially impacting the efficiency of training programs and student engagement [4]. Finding a balance between comprehensiveness and time constraints remains a challenge.

Cost-Effectiveness for Institutions: Developing and delivering standalone ERM courses may require additional resources for MET institutions. The cost-effectiveness of such programs needs to be carefully considered, especially for institutions with limited resources.

Instructor-Based Training:

Limited Focus on Practical Skills: Traditional lecture-based training methods focus on theoretical knowledge transfer. This approach may not adequately equip trainees with the practical skills required for effective teamwork and decision-making in dynamic engine room environments [10].

Inefficiency in Preparing for Real-World Scenarios: Lecture-based methods might not effectively prepare trainees for the time-sensitive and complex situations encountered in real-world engine room operations. Applying knowledge and making quick decisions under pressure is crucial, and current methods may not fully address this need.

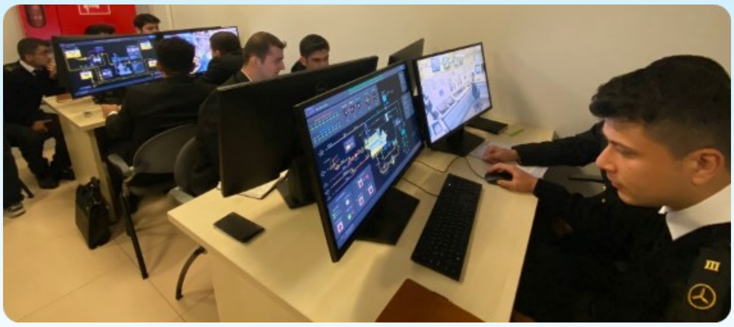

Figure 1. Students are in training using student workstations

The limitations of the fragmented approach, standalone courses, and lecture-based training methods collectively hinder the effectiveness of current ERM training. These methods often fail to provide a comprehensive and efficient training experience. The lack of standardization, fragmented curriculum integration, and limited focus on practical skills hinder the ability of ERM training to fully prepare future maritime professionals for the complexities of the engine room.

3. Methodology

3.1. Conceptual Framework

This section introduces the proposed Distributed Engine Room Simulator (ERS) Model designed to address the limitations identified in current ERM training methods. This model leverages a collaborative teamwork training approach facilitated by a distributed ERS system with multiple touch panels. The proposed ERS model incorporates the following critical aspects of training technologies and methodology:

Use of Distributed Architecture: The ERS model is designed with a distributed architecture, allowing for seamless integration of multiple simulation panels and interactive displays. Each panel, measuring 65 inches in size, is a dedicated workstation for specific engine room roles, including Chief Engineer, Second Engineer, Third Engineer, and Electro-Technical Officer (ETO). This distributed setup enables cadets to assume different engine room positions and collaborate effectively in a simulated environment.

Touchscreen Interface: The ERS model incorporates intuitive touchscreen interfaces on each panel, facilitating user interaction and control of engine room systems and equipment. Cadets can access essential functions, monitor system parameters, and execute commands using touch-based controls, mimicking the interface of actual engine room control systems. This user-friendly interface enhances cadets' familiarity with modern maritime technology and promotes hands-on learning.

Realistic Simulation Scenarios: The ERS model offers various realistic simulation scenarios, replicating various engine room situations, challenges, and emergencies in actual maritime operations. From routine maintenance tasks to complex machinery malfunctions, cadets are immersed in dynamic scenarios that require critical thinking, problem-solving, and collaborative decision-making. By experiencing these scenarios firsthand, cadets develop practical skills and confidence in handling engine room operations effectively.

Role-Based Training: The ERS model supports role-based training, allowing cadets to assume different engine room positions and responsibilities within simulated scenarios. Cadets can rotate between roles, experiencing firsthand each position's unique challenges and responsibilities, including monitoring equipment performance, troubleshooting faults, and coordinating team activities. This experiential learning approach enhances cadets' understanding of engine room dynamics and fosters teamwork and collaboration.

Performance Monitoring and Assessment: The ERS model includes built-in performance monitoring and assessment features, allowing instructors to track cadets' progress and develop competency in real time. Performance metrics, such as response times, decision-making effectiveness, and communication skills, are recorded and analyzed to provide constructive feedback and tailor training interventions. This data-driven approach enables personalized learning pathways and ensures cadets meet the required engine room resource management proficiency standards.

The proposed Distributed ERS model is designed to address the limitations of current ERM training methods by effectively integrating the essential competencies outlined in IMO Model Course 2.07 and aligning them with the STCW convention. This section explores how this integration is achieved within the ERS framework.

3.2. Competency Mapping and Scenario Design

A competency matrix is developed to map the specific learning objectives of IMO Model Course 2.07 to the STCW regulations and the corresponding skills assessed within the ERS scenarios. This ensures comprehensive coverage of all critical competencies required for effective engine room operations. The ERS scenario library will be designed to encompass a variety of situations that directly target the mapped competencies. These scenarios can include:

- Emergency Situations: Engine room fire, machinery malfunctions, loss of propulsion, etc.
- Routine Operations: Starting and stopping engines, switching fuel sources, performing routine maintenance, etc.
- Decision-Making Scenarios: Prioritizing tasks during emergencies, allocating resources, responding to alarms, etc.

By incorporating these mapped competencies into the scenario design, the ERS model allows trainees to apply their theoretical knowledge and develop the practical skills required by STCW regulations.

3.3. Assessment and Feedback Mechanisms

The ERS model integrates features for performance assessment and feedback to ensure effective learning and competency development:

Scenario-Based Assessment: Trainee performance within each scenario will be evaluated based on predefined criteria aligned with the targeted competencies. This could include communication effectiveness, teamwork skills, decision-making accuracy, and adherence to emergency procedures.

Instructor Monitoring and Feedback: Instructors can monitor trainee performance in real time through the ERS system and provide targeted feedback during and after each scenario. This allows for immediate course correction and reinforcement of key learning points.

Debriefing Sessions: Post-scenario debriefing sessions facilitate group discussions and self-reflection. Trainees can analyze their performance, identify areas for improvement, and learn from each other's experiences.

These assessment and feedback mechanisms allow for continuous evaluation of trainee progress and ensure the effectiveness of the ERS model in achieving the desired learning outcomes aligned with STCW and IMO Model Course 2.07. The training institutions usually utilize several configurations of the ERS in training the engineering cadets, in example stages, shown in Table 1.

Table 1. Training Stages and Methods of Simulator Use

Training Stage	Method of Simulator Use	Training Objectives and Assessment
1	Classroom. Learning by practices guided by the instructor, including briefings and de-briefings	Group activities. Familiarization. No assessment.
2	Laboratory. Full mission using software environment in student workstations. Individual practices of all objectives.	Individual practices for promoting the understanding of the responsibilities of each role. Individual assessment
3	Designated spaces. A full mission team environment with distributed actual hardware, touch panels, mimics, visual and audible alarms, and environmental effects.	Collaborative teamwork practices. Assessment within a team.

Figure 2 shows a typical individual assessment methodology using ERS. The objective assessment is essential for adequately evaluating the trainee's learning level.

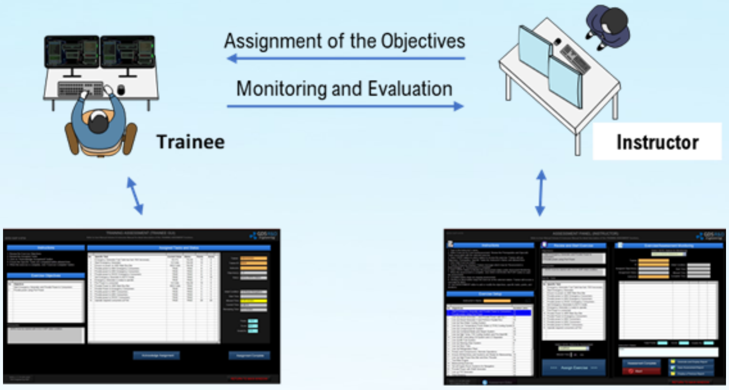

Figure 2. Individual Objective Assessment

3.4. Collaborative Teamwork

The proposed Distributed ERS model strongly emphasizes collaborative teamwork training, recognizing its critical role in effective ERM. This section explores how the ERS fosters this essential skill and addresses the limitations identified in current ERM training methods:

Enhanced Situational Awareness: Collaborative teamwork promotes shared situational awareness among engine room personnel, enabling them to collectively monitor vessel systems, assess operational conditions, and anticipate potential risks or challenges. Team members understand the operational environment comprehensively by exchanging real-time information, observations, and insights, facilitating proactive decision-making and risk mitigation strategies [6].

Improved Communication and Information Sharing: Effective communication is essential for successful teamwork in the engine room. Collaborative ERM training emphasizes developing communication skills, such as active listening, clear articulation, and assertive expression, to facilitate seamless information exchange and coordination among team members. By practicing communication protocols and strategies in simulated scenarios, engine room personnel learn to convey critical information accurately and efficiently, minimizing the risk of miscommunication and errors [8].

Optimized Resource Allocation and Task Management: Effective teamwork enables optimal resource allocation and task management in the engine room, ensuring that personnel and equipment are utilized efficiently to achieve operational objectives. Collaborative ERM training allows engine room personnel to coordinate activities, prioritize tasks, and allocate resources effectively within a simulated environment. By working together to address competing demands and constraints, team members develop the skills and strategies to optimize performance and productivity in real-world engine room operations [12].

Facilitated Decision-Making under Pressure: Engine room operations often involve high-pressure situations that require quick and effective decision-making. Collaborative ERM training prepares engine room personnel to make informed decisions under stress by simulating realistic scenarios and emergencies. Team members learn to assess options, weigh risks, and reach consensus in time-critical situations through collaborative problem-solving exercises and role-playing simulations. By practicing decision-making as a team, engine room personnel build confidence, resilience, and adaptability in the face of uncertainty [13].

Cultivation of Team Cohesion and Trust: Collaborative ERM training fosters the development of team cohesion, trust, and mutual reliance among engine room personnel. Team members build strong interpersonal relationships and camaraderie by working together to overcome challenges, resolve conflicts, and achieve common goals. This cohesion enhances crew morale, motivation, and job satisfaction, contributing to a positive safety culture and operational excellence in the engine room [7].

These collaborative teamwork skills are crucial for safe and efficient engine room operations. The ERS model equips future maritime professionals to work effectively as a team, ensuring smooth operation and rapid response to any challenges that may arise in the real world. The ERS model facilitates role-based training, assigning trainees specific roles within the simulated engine room environment. These roles can include:

- Chief Engineer: Takes overall command of the simulated engine room. Manages resources (personnel, equipment) and prioritizes tasks during emergencies and routine operations. Ensures efficient engine room operation, balancing fuel consumption, performance, and maintenance requirements. Implements safety protocols and ensures adherence to safety regulations.
- Second Engineer: Oversees the daily operations of the main engine and auxiliary equipment. Monitors engine performance parameters (temperature, pressure, RPM) and identifies potential issues. Troubleshoots minor engine malfunctions and performs routine maintenance tasks. Report engine status and any concerns to the Chief Engineer.
- Third Engineer: Focuses on auxiliary equipment operation and maintenance, including separators and fuel systems. Monitors separator performance and ensures proper fuel quality and cleanliness. Performs routine maintenance on auxiliary equipment and reports any abnormalities to senior engineers. Assists the Second Engineer with engine room tasks as needed.
- Electro-technical officer: Manages the engine room's electrical power generation, distribution, and control systems. Monitors electrical parameters (voltage, current) and identifies potential electrical faults. Responds to electrical emergencies and implement corrective actions to ensure safe operation. Communicates with other engineers regarding the status of the electrical system and any concerns.

By assuming these designated roles, cadets gain practical experience in communication, teamwork, and decision-making specific to each engine room position. This role-based approach mirrors real-world scenarios and prepares them for future careers at sea. There may be various applications of collaborative teamwork studies. Remembering the ERS as a tool for learning, these configurations may span from simple ones to the ones that are costly distributed environmental simulations.

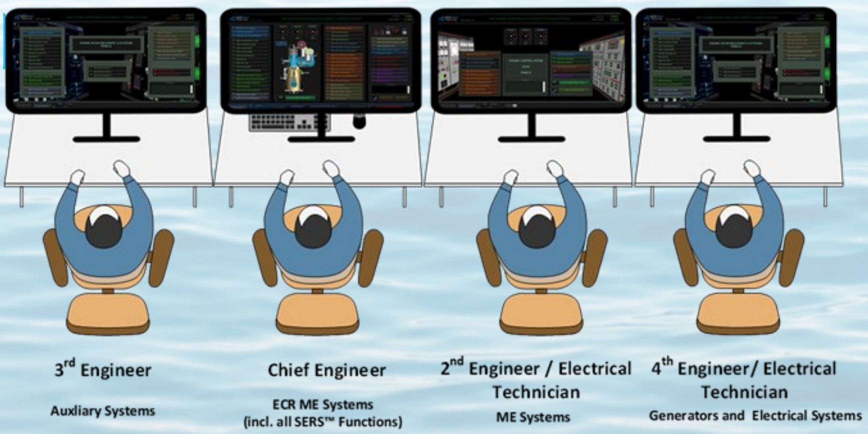

Figure 3. A basic workstation with distributed tasks to the students for effective teamwork

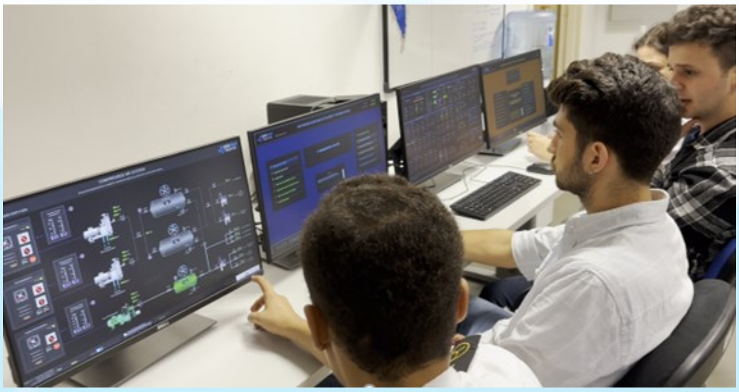

Figure 4. Four trainees are implementing the ERS exercises collaboratively

Another version of team training can be implemented in a Full Mission. We need to note that the Full Mission configuration. The full Mission term here refers to implementing the training using environmental simulations to increase realism. There may be many configurations. Figure 5 shows a typical Full Mission training environment with the engine room, instructor room, and engine control room (ECR) separated. The simulator usually includes alarm systems, sounds, and communication systems. Maritime institutions accept this configuration well; however, the authors know that many institutions cannot afford the cost and use only workstation configurations.

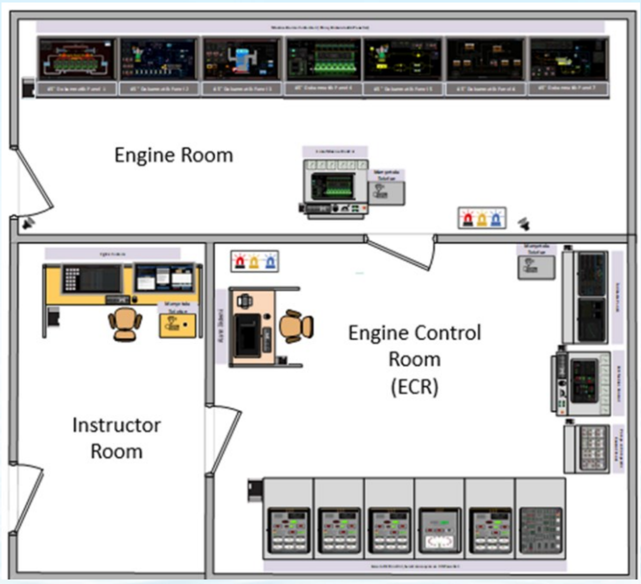

Figure 5. A typical Full Mission engine room simulator environment.

The authors have spent several years and completed funded projects to test several versions of the teamwork systems. Upon these studies, the authors proposed an optimized Full Mission simulator, which is cost-effective yet practical for teamwork with objective training methodologies. In this configuration, shown in Figure 6, 5 students are assigned different roles and responsibilities, based on IMO Model Course 7.02 and 7.04, and Imo Mode Course 2.07 contents are exercises with team study. The system shown in Figure 6 is currently installed at the Istanbul Technical University Maritime Faculty's Simulator Center. The simulator demonstration will be held during the IMLA Conference. Developed by GDS Engineering R&D, Inc. and called the Ship Engine Room Simulator for Team (SERS™4TEAM), the simulator has a modular architecture, meaning that additional hardware, consoles, alarm systems, and communication systems are all available by the manufacturer for selection based on the budget. SERS™4TEAM also allows for future upgrades with additional items to existing simulators. In this configuration, the instructors can assign students five roles: Chief, Second, Third, and Fourth Engineers and an Electrotechnical Officer (ETO). The relevant engine room systems are grouped as graphical user interface panels (GUI Panels) into different touch panels. The manufacturer provides more than 60 GU panels, and a configuration file allows the systems to be grouped into different touch panels. With this approach, the details of the systems are presented to the students interactively.

Figure 5. Optimized Team Working System with Consoles

3.5. Application Methodology

The proposed Distributed ERS model promotes a pre-existing, commercially available simulation software to create a realistic and interactive training environment. This section details the key components of the ERS setup, incorporating the adoption of the SERS™ (Ship Engine Room Simulator) software developed by GDS Engineering R&D and certified by Class NK as a Full Mission Engine Room Simulator.

Hardware Components:

Distributed Touch-Panel System: The core of the ERS is a network of four high-resolution, 65-inch touch panels. These panels will be strategically positioned to represent designated engine room workstations:

- o Main Engine Control Systems – Chief Engineer
- o Main Engine Systems – Second Engineer
- o Auxiliary Systems – Third Engineer
- o Diesel Generators and Electrical Systems – Electro-Technical Officer

Central Processing Unit (CPU): A high-performance CPU will run the ERS simulation software, manage communication between touch panels, and process user input.

Network Infrastructure: A secure network will connect all touch panels and the CPU, ensuring smooth data transmission and real-time interaction within the simulated environment.

Additional Hardware (Optional): Depending on the specific functionalities of the ERS, additional hardware components might be integrated. These could include:

- o Joystick controllers for simulating engine maneuvering
- o Sound systems for replicating engine noise and alarms
- o Gauges, buttons, indicators, etc.

Software Components:

SERS™ (Ship Engine Room Simulator) Software: The core software application driving the ERS will be the commercially available SERS™ software. Given its certification as a Full Mission Engine Room Simulator by Class NK, SERS™ is assumed to offer comprehensive functionalities, including:

- o Realistic engine room interfaces on each touch panel, mimicking actual control panels and instrumentation.
- o Simulation of engine and auxiliary equipment behavior based on user input and pre-programmed scenarios.
- o Generation of realistic engine data (temperature, pressure, alarms) for trainees to monitor and analyze.

o Communication features like voice chat and a shared information dashboard (subject to SERS™ capabilities).

Scenario Management Software (Integrated with SERS™): SERS™ likely incorporates its scenario management functionalities. Instructors can utilize these functionalities to:

o Select and launch specific scenarios for training sessions.

o Adjust scenario difficulty levels to cater to different trainee experience levels (subject to SERS™ capabilities).

o Monitor trainee performance and progress through the scenarios (subject to SERS™ capabilities).

Debriefing and Feedback Software: The ERS might integrate additional software tools to facilitate debriefing sessions and provide feedback. This could include:

o Recording and playback functionalities for scenario actions and decisions (compatibility with SERS™ recording features must be assessed).

o Annotation tools for instructors to highlight key learning points during debriefing sessions.

Integration with SERS™: The integration process between the touch-panel system, CPU, network infrastructure, and the SERS™ software will require careful consideration. The details will depend on the specific architecture and functionalities offered by SERS™. SERS™ will likely handle most of the simulation functionalities. At the same time, the custom software might focus on managing communication between workstations, facilitating the distributed environment, and potentially integrating additional debriefing or assessment tools. With the capabilities of the SERS™ software and combining it with a distributed touch-panel system, the ERS model can create a realistic and interactive training environment that fosters collaborative teamwork skills for future maritime professionals.

Proposed Configuration Advantages: The innovative configuration proposed in this study comprises one central control console and four strategically placed 65-inch touch panels. This setup facilitates a highly realistic simulation of a ship's engine room hierarchy, allowing students to assume roles such as Chief Engineer, Second Engineer, Third Engineer, Fourth Engineer, and Electrical Officer. Each student, operating from their respective touch panel, is tasked with managing and operating the systems under their designated responsibility via a unified software platform. This approach fosters collaborative decision-making, communication, and problem-solving skills for effective teamwork in a real-world maritime environment.

Cost-Effectiveness and Accessibility: The proposed configuration represents a significant advancement in providing cost-effective ERM training. The need for extensive hardware and dedicated space is minimized by consolidating multiple workstations into a single integrated system. This reduction in infrastructure requirements translates to a more accessible and affordable training solution for maritime education institutions. Furthermore, the centralized software platform streamlines training management and facilitates real-time monitoring and assessment of student performance.

4. Discussions

4.1. Evaluation of the ERS Model Effectiveness

The proposed Distributed ERS model presents a promising approach to enhancing ERM training for maritime professionals. This section explores potential methods for evaluating its effectiveness in achieving its intended learning outcomes.

<u>Qualitative Evaluation Methods:</u>

- **Trainee Feedback Surveys:** Conducting surveys after training sessions can gather valuable insights from trainees regarding their experience with the ERS model. Surveys can assess factors like:
    - Perceived realism and fidelity of the simulation environment.
    - Usability and ease of operation of the distributed touch-panel system.
    - Effectiveness of the role-based training approach in fostering teamwork skills.
    - Overall satisfaction with the learning experience provided by the ERS model.

- **Instructor Observations:** Instructors can provide qualitative feedback based on their observations of trainee behavior during ERS simulations. This feedback can address aspects like:
  - Effective communication and collaboration within the distributed environment.
  - Problem-solving and decision-making skills demonstrated by trainees during scenarios.
  - Ability of the ERS model to challenge trainees and encourage critical thinking.

Debriefing Session Discussions: Facilitating focused discussions during debriefing sessions allows trainees to share their experiences, identify areas for improvement, and collectively analyze their performance within the ERS scenarios. These discussions can provide valuable insights into the model's effectiveness in promoting learning and teamwork skills.

Quantitative Evaluation Methods:

Scenario-Based Performance Assessment: The ERS model can be designed to track and evaluate trainee performance within pre-programmed scenarios. This could include metrics like:

- Time taken to complete a scenario.
- Number and type of errors made during decision-making.
- Efficiency and effectiveness of communication and collaboration within the team.

Pre- and Post-Training Assessments: Standardized tests or knowledge assessments can be administered before and after training using the ERS model. This allows for a quantitative comparison of trainee knowledge and understanding of ERM principles before and after using the ERS, potentially demonstrating the model's effectiveness in knowledge retention and skill development.

Longitudinal Studies: Longitudinal studies tracking the performance of graduates trained using the ERS model compared to graduates from traditional training methods could be conducted over an extended period. This can provide insights into the long-term impact of the ERS model on maritime professionals' professional competencies and teamwork skills.

By employing a combination of qualitative and quantitative evaluation methods, the effectiveness of the ERS model in achieving its learning objectives can be comprehensively assessed. Positive evaluation outcomes can validate the model's contribution to improved ERM training and its potential to enhance future maritime professionals' preparedness and teamwork skills.

4.2. Comparison with Existing ERM Training Approaches

The proposed Distributed ERS model offers several advantages over traditional ERM training methods:

Fragmented Approach: Traditional ERM training often segments knowledge across various courses, hindering the development of a holistic understanding.

Standalone Courses: Standalone ERM courses can be time-consuming and resource-intensive for MET institutions.

Lecture-Based Training: Lecture-based approaches may not adequately prepare trainees for the practical application of knowledge and teamwork skills in real-world engine room scenarios.

Integrated Learning: The ERS model integrates ERM principles into a cohesive training environment, fostering a holistic understanding of best practices.

Improved Efficiency: The distributed architecture allows for efficient training of multiple trainees simultaneously, potentially reducing training time compared to standalone courses.

Practical Skill Development: The ERS model emphasizes role-based training and scenario-based learning, providing trainees hands-on experience in communication, teamwork, and decision-making within a simulated engine room environment.

Scalability and Adaptability: The ERS model can accommodate different training needs by adjusting scenario difficulty and incorporating additional functionalities based on specific requirements.

Standardized Training: The ERS model promotes standardized training across MET institutions, ensuring consistent learning outcomes for future maritime professionals.

Assessment and Feedback: The ERS model facilitates performance assessment and feedback, allowing instructors to identify areas for improvement and personalize training strategies.

Overall, the ERS model presents a more comprehensive and practical approach to ERM training than traditional methods. Promoting teamwork skills and replicating real-world engine room challenges equips future maritime professionals with the necessary knowledge and practical abilities to excel in their careers.

4.3. Implications for Maritime Education and Training (MET) Institutions

The Distributed ERS model offers a range of potential benefits for MET institutions seeking to enhance the quality and effectiveness of their ERM training programs.

Reduced Training Time: The distributed architecture allows for simultaneous training of multiple cadets, potentially reducing overall training time compared to traditional standalone ERM courses.

Standardized Training: The ERS model promotes standardized training across different MET institutions, ensuring consistent learning outcomes for future maritime professionals.

Practical Skill Development: The ERS model emphasizes role-based training and scenario-based learning, providing cadets with hands-on experience in communication, teamwork, and decision-making within a simulated engine room environment.

Deeper Knowledge Retention: This model's interactive and engaging nature can improve knowledge retention compared to traditional lecture-based approaches.

Assessment and Personalized Learning: The ERS model facilitates performance assessment and feedback, allowing instructors to identify areas for individual improvement and personalize training strategies to address specific needs.

Cost-Effectiveness: While initial investment may be required, the ERS model's potential to reduce training time and improve training efficiency can lead to cost savings in the long run.

Scalability and Adaptability: The ERS model can accommodate different MET institutions' specific needs and resources by adjusting scenario difficulty and incorporating additional functionalities.

Enhanced Reputation: MET institutions adopting the ERS model can showcase their commitment to innovative and effective training methods, potentially attracting a wider pool of qualified maritime cadets.

4.4. Limitations and Future Directions

The Distributed ERS model offers a significant advancement in ERM training; however, some limitations must be considered for future development.

Technical Expertise: Maintaining and operating the ERS model might require technical expertise for troubleshooting and software updates.

Fidelity and Realism: While the ERS strives for a realistic environment, it may not fully replicate the complexities and stresses of an actual engine room.

Focus on Specific Scenarios: The ERS model's effectiveness relies on its comprehensiveness and variety of pre-programmed scenarios.

Integration with Advanced Technologies: Future iterations could integrate virtual reality (VR) or augmented reality (AR) for an even more immersive training experience.

Standardized Scenario Library: Developing a standardized scenario library across MET institutions can promote knowledge sharing and ensure comprehensive training coverage.

Real-Time Data Integration: Future ERS models could potentially integrate with real-time engine data from operational vessels to enhance the realism of simulated scenarios.

Advanced Assessment Tools: Developing more sophisticated assessment tools that analyze communication patterns and teamwork effectiveness within the ERS can provide even richer insights into trainee performance.

5. Conclusion

5.1. Summary of Findings

This research investigated the potential of a Distributed ERS model to address shortcomings in current ERM training for maritime professionals. The proposed ERS model tackles these limitations by:

- Integrating competencies outlined in IMO Model Course 2.07 and STCW regulations into the design of pre-programmed scenarios.
- Utilizing a distributed touch-panel system that fosters a realistic and collaborative training environment.
- Emphasizing role-based training and teamwork skills development through features like communication tools and shared information dashboards.
- Employing scenarios with varying difficulty levels to challenge trainees and encourage critical thinking.

The ERS model offers several advantages over traditional ERM training methods. These include improved training efficiency by allowing simultaneous training for multiple participants, enhanced learning outcomes through practical skill development in a simulated environment, deeper knowledge retention due to interactive and engaging scenarios, standardized training across MET institutions for consistent learning outcomes, and scalability and adaptability to cater to the specific needs of different institutions.

The ERS model significantly benefits both MET institutions and future maritime professionals. MET institutions can improve training quality and efficiency, potentially reducing costs. Future maritime professionals gain practical skills, teamwork experience, and enhanced preparedness for challenges in real-world engine room settings.

5.2. Contributions to ERM Training Practices

This research has explored the potential of a Distributed ERS model to revolutionize ERM training for maritime professionals. The proposed ERS model offers significant contributions to current ERM training practices by:

- Bridging the Gap Between Theory and Practice: Traditional ERM training often struggles to bridge the gap between theoretical knowledge and practical application in a real-world engine room environment. The ERS model addresses this by:
    - Integrating STCW Regulations and IMO Model Course Competencies: The scenario design aligns with industry standards and learning objectives, ensuring trainees develop the essential skills required onboard.
    - Role-Based Training and Scenario-Based Learning: Trainees experience the complexities of teamwork and decision-making in a simulated engine room, replicating real-world challenges and fostering practical skill development.
- Fostering Collaborative Teamwork Skills: Effective communication and teamwork are crucial for safe and efficient engine room operations. The ERS model promotes these vital skills through:
    - Distributed System and Communication Features: Trainees practice communication across workstations, replicating real-world collaboration and task delegation within the engine room team.
    - Scenario Design: Scenarios encourage collaborative problem-solving, requiring trainees to analyze situations, communicate effectively, and make collective decisions.
- Enhancing Learning Effectiveness and Engagement: The ERS model departs from traditional lecture-based methods, promoting a more engaging and interactive learning experience through:
    - Interactive Scenarios: Pre-programmed scenarios with varying difficulty levels challenge trainees, promote critical thinking, and encourage the application of theoretical knowledge.
    - Performance Assessment and Feedback: The ERS model provides immediate feedback on decisions and actions within scenarios, allowing for self-reflection and continuous learning improvement.
- Promoting Standardized Training Across Institutions: The ERS model, with its standardized scenario library and core functionalities, has the potential to:

- Ensure Consistent Learning Outcomes: Trainees from different MET institutions receive consistent training aligned with industry standards, preparing them equally for their careers.
- Scalability and Adaptability: The model can be adapted to accommodate the specific needs of different institutions by adjusting scenario difficulty and incorporating additional functionalities.

The proposed Distributed ERS model presents a promising approach to enhancing ERM training for maritime professionals. This section outlines recommendations for future research and implementation efforts to refine the ERS model further and realize its full potential.

5.3. Recommendations for Future Research and Implementation

Standardized Scenario Library Development: Research efforts should focus on developing a comprehensive and standardized scenario library across MET institutions. This library should encompass routine operations, emergencies, and decision-making challenges, ensuring comprehensive training coverage.

Integration with Advanced Technologies: Future research can explore the potential of integrating virtual reality (VR) or augmented reality (AR) technologies into the ERS model. This could create an even more immersive and realistic training environment for trainees.

Advanced Assessment Tools: Developing more sophisticated assessment tools that analyze communication patterns, teamwork effectiveness, and leadership behaviors within the ERS can provide even richer insights into trainee performance and areas for improvement.

Longitudinal Studies: Conducting longitudinal studies to track the performance of graduates trained using the ERS model compared to graduates from traditional methods can provide valuable insights into the long-term impact of the ERS on the professional competencies and teamwork skills of maritime professionals.

Cost-Effectiveness: Strategies for cost-effective implementation should be explored. This could involve open-source software alternatives, collaborations with MET institutions to share development costs, or potential grant funding opportunities within the maritime training sector.

Faculty Development: MET institutions adopting the ERS model may require faculty development programs to ensure instructors can effectively utilize the technology and facilitate scenario-based learning within the ERS environment.

Scalability and Adaptability: The ERS model's design should accommodate different MET institutions' training needs and resource constraints. This could involve offering modular components or customizable features.

The ERS model represents a significant step forward in ERM training. By pursuing the recommended research directions and addressing implementation considerations, it can be refined and disseminated across MET institutions. This can revolutionize ERM training, equipping future maritime professionals with the necessary skills and knowledge to ensure safe, efficient, and collaborative operations at sea.

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References

[1] M. H. Dewan, R. Godina, M. R. K. Chowdhury, C. W. M. Noor, W. M. N. W. Nik, and M. Man, "Immersive and non-immersive simulators for the education and training in maritime domain—A Review," Journal of Marine Science and Engineering, vol. 11, no. 1, p. 147, 2023.

[2] G. Praetorius, C. Hult, and C. Österman, "Maritime resource management: current training approaches and potential improvements," TransNav, International Journal on Marine Navigation and Safety of Sea Transportation, vol. 3, no. 14, pp. 573-584, 2020.

[3] J. An, Y. Liu, D. Du, T. Wang, R. Liu, L. Fang, Y. Sun and C. Liu, "An evaluation of the engine-room resources based on the analytic hierarchy process approach," Open Journal of Social Sciences, vol. 7, no. 10, pp. 144-160, 2019.

[4] J. P. Chan, R. Norman, K. Pazouki and D. Golightly, "Autonomous maritime operations and the influence of situational awareness within maritime navigation," WMU Journal of Maritime Affairs, vol. 2, no. 21, pp. 121-140, 2022.

[5] IMO, Model Course 2.07: Engine-Room Simulator, International Maritime Organization, 2017.

[6] E. Salas, D. L. Reyes, and S. H. McDaniel, "The science of teamwork: Progress, reflections, and the road ahead," American Psychologist, vol. 73, no. 4, p. 593, 2018.

[7] J. Ernstsen and S. Nazir, "Consistency in the development of performance assessment methods in the maritime domain," WMU Journal of Maritime Affairs, vol. 1, no. 17, pp. 71-90, 2018.

[8] M. R. Endsley, "Situation Awareness in Teams," Contemporary Research, vol. 1, no. 1, pp. 1-27, 2020.

[9] E. Salas, K. A. Wilson, C. S. Burke, and D. C. Wightman, "Does crew resource management training work? An update, an extension, and some critical needs," Human factors, vol. 2, no. 48, pp. 392-412, 2006.

[10] W. Yao, D. Jiang, Y. Liu, and J. Zhang, "The Research and Development of Remote Interactive Engine Room Resource Management Simulator," in 2nd International Conference on Electronic & Mechanical Engineering and Information Technology, 2012.

[11] P. O'Connor, "Assessing the effectiveness of bridge resource management training," he International Journal of Aviation Psychology, vol. 4, no. 21, pp. 357-374, 2011.

[12] I. Cicek, B. Cavusoglu and M. Y. C. Berk Guler, "Online and Remote Training Experience in the Engine Room Simulator Training Courses using the IMO Model Course 2.07 Exercises," Varna, 2023.

[13] S. C. Mallam, S. Nazir and S. K. Renganayagalu, "Rethinking Maritime Education, Training, and Operations in the Digital Era: Applications for Emerging Immersive Technologies," Journal of Marine Science and Engineering, vol. 7, no. 12, p. 428, 2019.

[14] B. &. K. S. Stewart, "Performance improvement through engine room resource management training: A longitudinal study," Journal of Occupational and Organizational Psychology, vol. 3, no. 94, pp. 478-495, 2021.