Bridging the Gap: Immersive Technologies and Active Learning in Modern Naval and Maritime Education

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Abstract. This study aims to critically analyse the evolution of Maritime Education and Training (MET), proposing solutions to fill the gap between theoretical training and operational practice. In the current context of increasingly complex, digitalised and automated socio-technical systems onboard, MET has shifted from traditional onboard situated learning models to more formalised and standardised approaches, such as decontextualised learning in the classroom. However, the current education system is often associated with limitations in the development of non-technical and adaptive skills. Methodologically, this study takes a historical-prospective approach, drawing on a critical review of scientific literature and relevant international regulatory frameworks. The results demonstrate that active learning methodologies supported by immersive technologies, such as simulation, virtual reality, and augmented reality, can significantly strengthen the connection between theory and practice in safe, controlled environments. Therefore, the study proposes a competency-based hybrid model of education and training that integrates theoretical teaching, immersive simulation and supervised onboard experience. The study concludes that the evolution of MET should be based on an integrated, contextualised pedagogical approach that aligns with contemporary demands in the maritime sector.
Keywords: active learning; competency-based training; maritime education and training (MET); simulation; virtual and augmented reality.

1. Introduction

Maritime operations take place in complex socio-technical environments characterized by uncertainty, operational pressure, isolation and a need for high safety standards. In such environments, the interaction between advanced technological systems and human factors plays a decisive role. Unlike in other industries, maritime professionals' performance depends on an integrated combination of technical, cognitive, social, and behavioral skills. This combination enables them to act effectively in situations of uncertainty, pressure, and potential emergency.

Traditionally, maritime training has focused on experiential learning and the transmission of tacit knowledge in a real-life context, based on a master-apprentice relationship. This model fostered a strong connection to the real work context, promoting autonomy and practical skill development. However, it presented limitations in terms of variability in training quality, lack of standardization, and dependence on experienced instructors.

The increasing technological complexity and globalization of the sector have led to the need for international standardization of professional qualifications. This has reinforced the formal, theoretical component of land-based training, as evidenced by the STCW (Standards of Training, Certification and Watchkeeping for Seafarers) Convention (IMO, 2017). Despite advances in curriculum structure, certification and scientific basis, the contemporary model has introduced new challenges. Notably, there is a disconnect between the theoretical training provided in an academic environment and the operational reality experienced onboard. This results in reduced exposure to decision-making processes in real-world contexts, as well as the underrepresentation of the social and cultural dimensions of maritime life. The literature has identified this as a structural gap in maritime education with direct implications for the effective preparation of professionals for complex operational contexts (Gekara & Sampson, 2021; Sellberg, 2025).

At the same time, technological evolution in the maritime sector, characterized by increasing automation, digitalization, and systems integration, is redefining the skills required of professionals. Alongside the technical skills required to operate increasingly sophisticated systems, it is crucial to cultivate situational reasoning, risk analysis, decision-making in uncertain environments, leadership, intercultural communication and emotional management abilities. These skills, often referred to as non-technical or transversal, highlight the need for pedagogical approaches that go beyond the traditional teaching model to promote active, contextualized, student-centered learning.

Active learning methodologies such as simulation, problem-based learning, role-playing and project-based learning are particularly well-suited to maritime training in this context, as they replicate real operating conditions. The development and increasing accessibility of immersive technologies, including advanced simulators, virtual reality (VR) and augmented reality (AR), also open up new possibilities. These technologies enable the creation of safe, controlled, highly realistic learning environments in which critical scenarios can be reproduced, complex skills developed, and reflection on action encouraged, without any of the risks associated with the real world.

Integrating these methodologies and technologies into the training process has led to the development of hybrid teaching models that combine classroom-based theoretical instruction with practical training in simulated or immersive environments, as well as supervised experience at sea. These models aim to retain the strengths of traditional situated learning paradigms while incorporating the advantages of standardization and the scientific basis of formal education. In this sense, hybrid training is a promising approach for reducing the gap between theory and practice, promoting progressive and safe learning that aligns with contemporary demands in the maritime sector (Oliveira et al., 2022; Sellberg, 2025).

This study aims to critically analyze the evolution of Maritime Education and Training (MET), identifying the main pedagogical gaps in traditional and contemporary models and evaluating the potential of active learning methodologies supported by immersive technologies to address these gaps. Additionally, the intention is to propose a holistic, competency-based teaching model that coherently integrates different learning environments and strategies. This will encourage reflection on pedagogical innovation in naval and maritime higher education, influencing curriculum design, accreditation processes, and the relationship between educational institutions and the maritime industry.

2. Methods

The study takes a qualitative approach, based on a historical-prospective analysis of the evolution of MET. This is complemented by a critical review of recent scientific literature and international normative documents. The analysis is further supported by the practical experience of professionals, enabling theoretical evidence to be articulated alongside operational perspectives. Based on this, the study identifies pedagogical gaps and constructs a conceptual proposal for a hybrid training model focused on integrated competency development.

The interpretation of the data enables the study to pinpoint these gaps and develop a hybrid conceptual model integrating different competency-based learning environments.

3. Results

3.1. Evolution of MET, from the traditional to the contemporary model

MET has evolved in response to technological, organizational, and regulatory changes within the maritime sector. This is evident in the shift from the traditional experiential model, which focused on onboard learning, to the contemporary model that is based on formal training and international standardization. The coexistence of these two models highlights unresolved structural tensions.

Historically, seafarer training was developed primarily in an operational context through informal, contextualized learning. This approach was rooted in the logic of a master–apprentice relationship, where knowledge was conveyed progressively and contextually, incorporating the technical, operational, and cultural aspects of the profession. Direct onboard experience enabled total immersion in the maritime environment, supporting the development of practical skills, autonomy and adaptability in response to changing conditions. A central element of this paradigm was the transmission of tacit knowledge acquired through observation, repetition, and participation in real activities (Matos, 2012). Instruments such as the student logbook played a significant role in structuring learning by enabling the recording of experiences, reflection on practice and monitoring of formative progress.

Despite its advantages, this model had significant limitations. The quality of training depended heavily on the experience and availability of instructors, resulting in inconsistent outcomes. Furthermore, the absence of normative benchmarks made it difficult to compare the competencies of professionals internationally, which compromised the consistency of training.

As ships and navigation systems became more technologically complex and global maritime transport intensified, the need to structure and standardise the education and training of maritime professionals increased. This resulted in the formalisation of maritime education, with an increasing emphasis placed on structured learning in specialist institutions.

A key milestone in this process was the implementation of international normative frameworks, particularly the STCW Convention, which set out minimum global standards for training, certification and competencies. The contemporary model has strengthened trainees' theoretical foundation, ensuring minimum qualification levels and promoting the international harmonisation of training practices. This evolution has had the unintended consequence of distancing trainees from operational reality. While academic training is vital for understanding the underlying systems and principles, it offers limited opportunity to experience real-life decision-making scenarios under pressure. Reduced exposure to the onboard context can also hinder the development of social and cultural skills specific to maritime life, as well as the internalisation of informal safety and operational efficiency practices.

A comparative analysis of the two paradigms reveals a dichotomy between experience and standardisation, and between situated practice and theoretical abstraction. The traditional model prioritises immersion and the contextualised development of skills, whereas the contemporary model ensures consistency, rigour, and formal recognition. Nevertheless, neither model fully meets the current demands of the maritime sector.

This tension creates a persistent pedagogical gap, often characterised as a mismatch between land-based training and operational practice at sea. This gap is particularly problematic in situations where professionals are required to operate highly complex systems, make decisions in uncertain environments, and manage multicultural teams in challenging circumstances.

Clearly, training models in this context need to be redesigned to combine the strengths of both approaches. The future evolution of maritime training should therefore be oriented towards approaches that reconcile theoretical rigour with contextualised practice. This can be achieved by using methodologies and technologies that recreate the complexity of the maritime environment safely and controllably. Hybrid training approaches will be analysed in the following sections.

3.2. Emerging Competencies in the Maritime Sector

The ongoing evolution of the maritime sector, driven by digitalisation, automation, and the increasing integration of complex systems, necessitates a redefinition of the required professional skills. Modern ships are highly interdependent socio-technical systems, and the interaction between advanced technology and human factors is critical for operational safety and efficiency. In this context, professional performance is not solely based on technical expertise, but requires a combination of multidimensional skills (Oksavik et al., 2020).

Technically, professionals must be able to operate and supervise increasingly sophisticated systems, including automated platforms, integrated navigation systems, and digital decision-support tools. This reality demands specialised knowledge, digital literacy and the ability to adapt to ever-evolving technologies. At the cognitive level, developing situational reasoning, risk analysis and decision-making skills in uncertain, ambiguous and time-pressured environments is particularly important.

In addition to these dimensions, social and behavioural skills are also becoming increasingly important. The multicultural nature of modern crews implies the need for high levels of competence in intercultural communication, leadership and teamwork. The psychological demands of life at sea, such as isolation, operational stress, and exposure to critical situations, further emphasise the importance of resilience, emotional regulation, and maintaining performance under pressure (Conceição et al., 2017).

These demands highlight the need for a holistic training approach that promotes the integrated development of technical and non-technical skills. Furthermore, in a context of rapid technological evolution, it is essential to prepare professionals to perform specific tasks and to continuously learn, adapt to new systems and respond to unforeseen scenarios. The increasing automation of ships and the development of autonomous vessels further emphasise the need for a combination of technical operational skills and the ability to interpret complex digital systems. Therefore, contemporary maritime training must prioritise developing critical thinking skills, autonomy and a commitment to lifelong learning alongside acquiring knowledge (Água et al., 2020; Belabyad et al., 2026).

3.3. Limitations of traditional models

The emerging demands of the maritime sector highlight the inadequacy of traditional pedagogical models for effectively preparing professionals. This teaching paradigm centres on the teacher as the source of knowledge and positions the student as passive, and is often oriented towards memorising and reproducing content. While this model facilitates the effective communication of structured information, it is not ideal for developing complex skills, especially those related to decision-making, critical judgement and performing in dynamic situations. One of the model's main limitations is its inability to replicate the complexity and unpredictability of real operational environments. Decontextualised learning hinders the application of knowledge in practical situations, especially in scenarios involving multiple interacting variables. Consequently, students may struggle to apply theoretical knowledge in real-life situations at sea, where pressure, time constraints, and uncertainty can impact decision-making processes.

Furthermore, traditional models predominantly value lower-level cognitive skills, neglecting the development of non-technical abilities such as leadership, communication, teamwork and stress management. However, these skills are crucial in a maritime context, where effective coordination among crew members and the ability to manage critical situations are key to operational safety.

Another relevant aspect relates to the evolving role of the teacher. In an era of widespread, constantly updated information, teachers are shifting their focus from transmitting content to facilitating learning. This requires the adoption of pedagogical strategies that encourage active student participation, critical reflection, and autonomous knowledge construction.

Clearly, while traditional pedagogical models still play a relevant role in structuring theoretical knowledge, they are insufficient on their own to meet the demands of contemporary maritime training. Therefore, it is imperative that maritime education evolves to incorporate more dynamic, student-centred, practice-oriented approaches.

3.4. Potential of active learning methodologies

The growing complexity of the maritime sector and the need to develop both technical and non-technical skills have led to active learning methodologies being adopted in maritime education. These approaches treat students as active participants in their own learning, encouraging them to solve problems and apply knowledge in contexts that closely resemble operational reality.

One of the most relevant methodologies in this field is simulation, which is widely used in the training of maritime personnel. It recreates operational scenarios with a high degree of realism, providing an opportunity to develop technical and behavioral skills in a controlled environment. Simulation strengthens experiential learning by enabling trainees to make decisions, observe the consequences of these decisions and reflect on their performance, free from the risks associated with real-life situations. Additionally, methodologies such as problem-based learning (PBL) and the case method promote critical thinking and analytical skills by placing students in situations that require the integration of multidisciplinary knowledge. Role-playing, project-based learning, and the flipped classroom approach foster students' autonomy and teamwork skills while encouraging them to integrate theory and practice. These methodologies are particularly suited to the maritime context, where collaborative decision-making and managing unforeseen situations are critical.

Technological advancements in immersive technologies, such as virtual reality (VR) and augmented reality (AR), have led to the development of sophisticated simulators capable of creating highly realistic, interactive learning environments (Dewan et al., 2023). These technologies can simulate critical scenarios such as system failures, adverse weather conditions and emergency situations. This provides valuable learning opportunities by offering experiences that closely resemble real operational situations (Tusher et al., 2026).

For example, VR allows users to be fully immersed in three-dimensional environments, which is useful for training in intricate procedures and familiarizing oneself with spaces and equipment. Conversely, AR can overlay digital information onto the physical environment, supporting contextualized learning and real-time task execution. These tools increase student engagement, improve knowledge retention and enable systematic repetition of exercises, which is essential for consolidating skills.

However, despite their potential, integrating these technologies into active learning methodologies should be guided by clear pedagogical objectives rather than a focus on technology alone. The effectiveness of active learning methodologies depends on their alignment with curricular content and assessment models, as well as teachers' ability to design and facilitate meaningful learning experiences.

In this context, active learning methodologies supported by immersive technologies are vital for aligning the training process with the real demands of the maritime sector. Adopting these methodologies allows us to overcome the limitations of traditional models, promoting deeper, contextualized learning and the development of the necessary professional skills for working in complex and high-risk environments.

4. Discussion and model proposal

MET is undergoing a paradigmatic transition, driven by the growing complexity of maritime systems and the redefinition of professional skills. Although the transition from experiential onboard learning to standardized, formal training has resulted in substantial organizational and certification enhancements, it has also created a disparity between theory and practice.

This mismatch is a significant limitation, particularly given that professionals must operate in complex socio-technical environments characterized by high levels of uncertainty and challenging decision-making processes. Analyzing the sector's new demands shows that effective performance depends on combining technical and non-technical skills. These include cognitive, social, and behavioral capabilities, which are difficult to develop using transmissive pedagogical models alone.

Active learning methodologies combined with immersive technologies have significant potential to make the training process more realistic. Simulation, virtual reality and other digital tools can recreate complex scenarios safely and under controlled conditions, thereby promoting experiential learning and the development of critical skills. However, these methods must be consistently integrated into the curriculum, guided by clear training objectives and aligned with the sector's normative frameworks to be effective.

In light of the limitations of traditional and contemporary MET models and the growing demands on the sector, this paper puts forward a conceptual model of hybrid education and training. This model coherently and systematically integrates different environments, methodologies and learning dimensions. Taking a holistic, competency-oriented approach, it combines rigorous theoretical training with rich practical experience and makes use of emerging technologies.

The proposed model is based on four key principles:

- Sociotechnical integration: It recognizes that performance in a maritime context is the result of the interaction between technological systems and human factors, and that training approaches must consider this interdependence (Gekara & Sampson, 2021).
- Competency-centered learning: Focusing on the integrated development of technical and non-technical skills that align with international benchmarks and the operational needs of the sector (IMO, 2017).
- Experiential and situated learning: Recognizing that practical experience, whether real or simulated, is a vital component of the training process and encouraging the application of knowledge in operational contexts (Kolb, 2015).
- Flexibility and adaptability: The ability to integrate different methodologies and technologies, and adapt the training process to technological evolution and institutional specifics.

The proposed conceptual model (Figure 1) is organized around three complementary and interconnected learning environments.

- Theoretical classroom teaching: It is responsible for the structured transmission of scientific and technical knowledge, providing the conceptual basis necessary for understanding maritime systems and processes. This environment continues to play an essential role, particularly in introducing fundamental concepts and systematizing knowledge.
- Immersive environments and simulation: These include simulators, virtual reality, and augmented reality, which allow operational scenarios to be recreated with a high degree of realism. In this context, trainees can apply their knowledge, make decisions and develop their skills in a safe and controlled environment. They benefit from immediate feedback and the opportunity to repeat tasks (Sellberg, 2025).
- Supervised onboard experience: This constitutes the real learning space in which trainees are exposed to the complexity of the operational environment, integrate into teams, and participate in real activities under supervision. This component is vital for consolidating competencies, internalizing professional practices and developing a maritime and organizational identity.

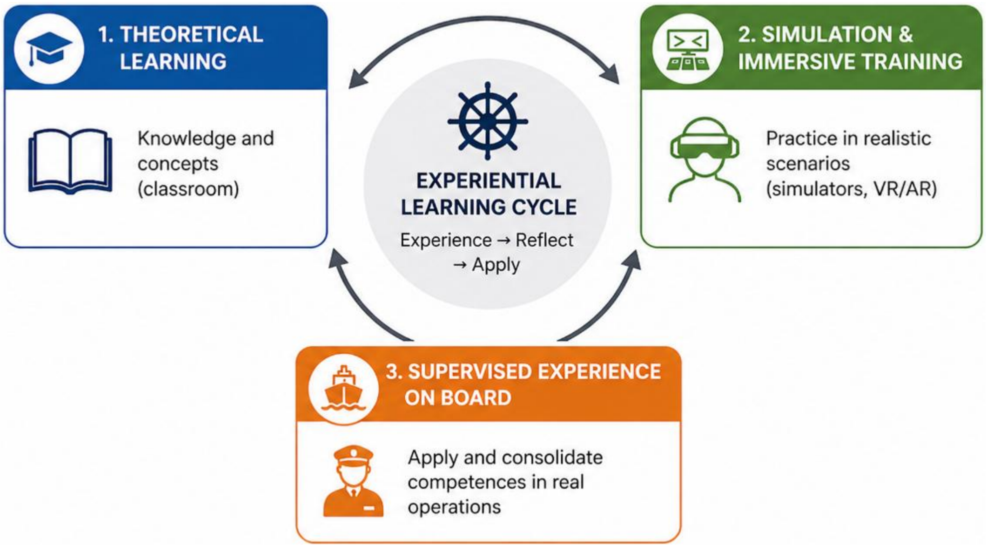

Figure 1: Hybrid Conceptual Model of Education and Training
Source: Image generated by ChatGPT

The three environments should be integrated in an iterative and progressive manner to allow continuous cycles of learning, application and reflection. The model thus adopts a cyclical experiential learning approach, in which concrete experience, reflection, conceptualisation, and experimentation mutually reinforce each other (Kolb, 2015).

The model explicitly integrates different dimensions of knowledge, competence and skills:

- Technical: systems operation, navigation, engineering, and specific procedures;
- Cognitive: situational reasoning, risk analysis and decision-making.
- Social: communication, leadership, and teamwork;
- Behavioural and psychological factors: resilience, stress management, and situational awareness.
- Transversal: critical thinking, professional ethics, and lifelong learning.

Integrating these dimensions is essential in order to respond to the multifaceted nature of the functions performed by maritime professionals and to avoid a fragmented approach to training.

In the proposed model, immersive technologies act as an interface between theoretical teaching and real-world practice. By enabling the simulation of complex scenarios and experimentation with critical situations, these technologies provide a safe and progressive 'intermediate space' for learning. This facilitates skill development in a controlled environment and also standardises formative experiences, reducing the variability associated with learning exclusively onboard, while facilitating objective performance evaluation by collecting specific data and indicators (Oliveira et al., 2022).

However, implementing this model presents challenges at institutional and pedagogical levels. In particular, it requires:

- Reformulating curricula to explicitly integrate active methodologies.
- Investing in adequate technological infrastructure.
- Providing pedagogical training for teachers and instructors.
- Strengthening collaboration between educational institutions and operational entities must also be strengthened.
- Adapting assessment models to prioritise competency-based assessment is also important.
- Aligning with international normative frameworks, particularly those defined by the IMO (2017), ensures that pedagogical innovation reinforces certification requirements rather than compromises them.

The proposed model seeks to address the limitations of existing paradigms by integrating their strengths into a coherent approach that meets the contemporary demands of the maritime sector. Combining theoretical teaching with immersive environments and practical onboard experience promotes more comprehensive, contextualised and effective learning. This contributes to the training of professionals who can act competently within complex socio-technical systems.

5. Conclusions and implications

MET is undergoing a paradigm shift, driven by the growing complexity of maritime systems and the redefinition of required professional skills. While the historical evolution from experiential onboard learning to formal, standardised training models has improved organisation and certification, there is now a mismatch between theoretical training and operational practice.

This gap is a critical limitation, particularly since professionals must work in complex socio-technical environments that are characterised by high levels of uncertainty and require effective decision-making. Analysis of the sector's new demands shows that effective performance requires a combination of technical and non-technical skills. These include cognitive, social and behavioural capabilities, which are challenging to cultivate through expository pedagogical models alone.

There is evidence to suggest that active learning methodologies combined with immersive technologies have significant potential to make training more realistic. Simulation, virtual reality, and other digital tools can recreate complex scenarios safely and in a controlled environment, thereby promoting experiential learning and the development of critical skills. However, this approach must be consistently integrated into pedagogy and guided by clear formative objectives aligned with the sector's normative frameworks.

This study therefore proposes a conceptual model of education and training combining theoretical teaching, immersive environments, and supervised onboard experience. The model aims to combine the strengths of traditional and contemporary approaches to promote progressive, contextualised, competency-based learning. Implementing this model could help reduce the mismatch identified in the current education system and better prepare professionals for current and future maritime sector challenges.

From the perspective of naval and maritime higher education, the implications are significant and require a critical analysis of current processes. Curricular models must be redesigned from the outset, shifting from a content-centred logic to a competency-based approach that explicitly recognises the non-technical aspects of professional performance. This transition requires programmes to be revised and pedagogical strategies and evaluation methods to be redefined. These changes will facilitate the adoption of approaches that enable performance to be observed and measured in realistic contexts.

The effective integration of immersive technologies requires sustained investment in infrastructure and, above all, in developing the pedagogical skills of teachers and instructors. Simply introducing technology does not guarantee improvements in the learning process. In fact, without adequate didactic integration, it can result in the resources being used ineffectively or superficially. Therefore, training teaching staff is a critical success factor.

It is also important to strengthen the connection between educational institutions and industry, ensuring that training models align with operational practices and the sector's real needs. Onboard experience should be incorporated into the training programme in a structured way, as an integral part of developing professional skills, not just to fulfil certification requirements.

Adapting accreditation criteria and normative frameworks poses an additional challenge. Current models, which focus heavily on content verification and training hours, may be unable to accommodate innovative, competency-centred pedagogical approaches. Therefore, more flexible, results-oriented assessment models that do not compromise the rigour or safety requirements of working at sea will be necessary.

Despite its contributions, this study has limitations stemming from its predominantly theoretical nature and the lack of empirical validation of the proposed model. Future research should implement and test the model in real educational and training contexts to evaluate its impact on skill development and professional performance.

In summary, naval and maritime higher education must produce decision-makers who can operate within complex systems by integrating knowledge, experience and judgement, rather than merely qualified technicians. One promising approach to meeting this challenge is to adopt hybrid models supported by active methodologies and immersive technologies. This would establish naval and maritime higher education as a space for pedagogical innovation, effectively connecting academic knowledge with operational practice.

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