

Maritime TVET in Transition: Global Trends, Institutional Innovation, and Strategic Reform

A.S. Kamis, A.F. Ahmad Fuad, S.A. Ali, W.N. Wan Mansor, S.Z.A. Syed Ahmad

& M.F. Ali Akhbar

University Malaysia Terengganu, Terengganu, Malaysia

ABSTRACT: The rapid transformation of the maritime industry, driven by technological advancements, digitalisation, and evolving regulatory frameworks, has created an urgent need to modernise maritime Technical and Vocational Education and Training (TVET). This review examines the current landscape, innovations, and challenges in maritime TVET by analysing a broad range of recent academic and institutional literature. The study identifies key areas of focus, including curriculum relevance, simulation-based and digital learning, competency-based education, and strong industry-academic collaboration. It highlights the importance of integrating emerging technologies such as e-learning, virtual reality, and smart glass to meet industry standards and prepare graduates for dynamic maritime careers. Additionally, it emphasises the necessity of expanding access to TVET pathways, upgrading instructor competencies, and aligning national policy with practical workforce demands. The findings underscore that a flexible, responsive, and industry-aligned TVET system, supported by sustainable funding, global collaboration, and policy reform, is essential for developing a future-ready maritime workforce capable of supporting sustainable growth.

1 INTRODUCTION

UNCTAD (2024) reports that global trade volume hit a record of 33 trillion USD, a 3.7% increase, or roughly 1.2 trillion more than in 2023. The expansion resulted in an increase in the need for maritime professionals, such as skilled seafarers, port workers, and logistics staff (Paryono, 2017). For this reason, maritime education and training is now an important part of making sure that people are capable of doing a variety of nautical jobs by giving them the knowledge and skills they need (IMO, 2018).

In 2021, the International Maritime Organisation (IMO) conducted a Regulatory Scoping Exercise (RSE) on Maritime Autonomous Surface Ships (MASS) to assess how existing IMO regulations could be adapted and applied to accommodate the operation of

emerging autonomous vessels (IMO, 2021b). Under environment protection, IMO has revised IMO Greenhouse Gas (GHG) Strategy, adopted in July 2023, and outlines clear targets for 2030, 2040, and 2050. According to RESOLUTION MEPC.377(80), by 2030, the carbon intensity of international shipping must be reduced by at least 40% compared to 2008 levels, and the use of zero- or near-zero-GHG emission technologies and fuels should account for at least 5% of the energy used, with an aspirational goal of 10%. By 2040, total annual GHG emissions from international shipping should be reduced by at least 70%, striving towards 80%. By 2050, the strategy aims for the shipping industry to reach net-zero GHG emissions, ensuring that it no longer contributes to global warming (IMO, 2023a).

These are among several new regulations and strategies introduced by the IMO as part of its ongoing efforts to support the United Nations Sustainable Development Goals (SDGs). Consequently, these initiatives have led maritime education and training (MET) providers around the globe to enhance their curricula to meet the IMO vision and industry standards (T. E. Kim et al., 2021; Paryono, 2017).

A comprehensive approach to maritime TVET that incorporates both theoretical and practical training has been highlighted by recent studies (Renganayagalu et al., 2022; Sharma et al., 2019). In TVET, practical hands-on training is prioritised over traditional classroom theory. A number of MET institutions have begun enhancing their training methods by adopting TVET-based approaches, including Akademi Laut Malaysia (ALAM). ALAM has introduced a new training model for ratings based on the Malaysian Skills Certificate framework, specifically utilising Malaysia Department of Skills Development's National Occupational Skill Standard (NOSS), H501-003-3:2019-Navigation Watchkeeping and Deck Operation for deck rating, and H501-002-3:2017-Marine Engine Maintenance Operation for engine rating (ALAM, 2019). This initiative not only improves instructional methods but also provides graduates with dual certification recognized both internationally and by the Malaysian government.

The industry necessitates exposing students to cutting-edge technologies alongside practical training. This rapid change in the industry requires students to be proficient in using the latest technology. As a result, simulation-based training and e-learning platforms have proven to be effective in enhancing student engagement and educational outcomes for maritime and shipping operations, meeting all industry demands (Sharma et al., 2019).

While delivering all training through the integration of simulators and e-learning, it is imperative for the training institute to meet the learning objective, as laid out in the course outline. Section B-I/6 of the Seafarers' Training, Certification, and Watchkeeping (STCW) Code requires that everyone involved must make sure that any distance learning and e-learning program achieves the necessary learning goals to provide important knowledge and skills in the subject (IMO, 2018). Nonetheless, obstacles including financial limitations, antiquated infrastructure, and a deficiency of competent educators persist as substantial impediments to efficient marine TVET (Sellberg, 2018)

2 THE PROBLEM STATEMENT AND RESEARCH AIM

The maritime sector is experiencing significant transformation due to the swift incorporation of innovative technologies, including automation and digitalisation (Nazir et al., 2015; Ziarati et al., 2010). If the traditional training approach fails to keep up with demand, it may risk a workforce that is inadequately prepared for the requirements of modern maritime operations (Bartusevičienė & Valionienė, 2021). The gap between the existing syllabus and training methodologies and industry standards may present a

significant obstacle and jeopardise the safety, efficiency, and competitiveness of the industry (Catalin, 2013). Consequently, it is essential to evaluate and rectify the shortfalls in maritime TVET to guarantee that the workforce is sufficiently equipped for the current and future setting (Reza Emad & Kataria, 2022).

This review article intends to conduct an analysis of the present condition of maritime TVET, explore the innovations made to the syllabus, including the program outline and teaching methods, pinpoint significant challenges and opportunities, and propose ideas for enhancing the quality and relevance of maritime education.

3 METHODOLOGY

3.1 *Research Design*

This study uses a qualitative research design targeted to review multiple research papers specifically in maritime TVET. But the study will include all research from various fields to avoid missing any variables or factors. The concept is to review research and consider all variables or factors from various fields of TVET programs. Then, the authors will engage in discussions to filter only the variables that can be integrated into maritime TVET.

3.2 *Data Collection*

This study utilised diverse sources, including peer-reviewed journal articles, industry reports, and regulatory documents, to develop a comprehensive understanding of contemporary trends and challenges in TVET that extends beyond the maritime sector. Furthermore, it examined practical instances from maritime institutions to demonstrate the application of innovative pedagogical methods and emerging technologies in practice. This entailed a thorough analysis of their curricula, pedagogical techniques, and strategies for delivering education innovatively and effectively.

The case studies were selected according to three primary criteria: (1) Relevance: institutions employing innovative methodologies in maritime education, particularly those incorporating technology and simulation-based learning; (2) Diversity: a range of institutions from various global regions that provide an international perspective on maritime TVET practices; and (3) Impact: institutions recognised for their significant contributions to the enhancement of maritime education and training.

3.3 *Collating, Summarising, and Reporting Results*

The next stage involves assigning appropriate labels to the identified factors and their corresponding sub-factors. According to Nowell et al. (2017), a factor can be derived either directly from raw data or thoughtfully based on existing theoretical frameworks. In this study, the researchers opted to reference prior studies to guide the naming of these factors. For instance, after analysing the collected data, it was found that the occurrences could be grouped into three

main categories: 1) the current state of TVET, 2) innovation, and 3) challenges and opportunities. As a result, Table 1 summarises the identified factors.

3.3.1 Current state of TVET

The current state of TVET was determined as the first factor in this research. As an outcome, the factors identified in this study can be divided into four sub-factors: 1) curriculum and pedagogy (CP), 2) technological integration (TI), 3) industry partnership (IP), and 4) challenges and barriers (CB).

3.3.2 Innovation

The second factor that was identified was innovation. It consists of 1) Simulation-Based Training (SBT), 2) E-Learning Platforms (ELP), 3) Competency-Based Education (CBE), and 4) Policy and Frameworks (PF)

3.3.3 Challenges and opportunity

Finally, the third factor identified was the challenges and opportunities presented by the project. The factor consists of 1) Funding and Resources (FR), 2) Instructor Training and Development (TD), 3) Curriculum Relevance (CR), and 4) Global Collaboration (GC)

Table 1. Thematic table summarizing the findings of the study

No	Author and year	Country	Synopsis	Focus of the study											
				Current state of TVET	Innovation	Challenges and opportunity		TD	CR	GC					
				CP	TI	IP	CB	SBT	ELP	CBE	PF	FR	TD	CR	GC
1	(Baldauf & Hong, 2016)	Not specified	This study used enhanced simulation-based team training to address maritime safety and security, utilizing specialized simulators to realistically represent on-board vessel conditions for emergency response and crisis management scenarios				√	√							
2	(Baylon & Santos, 2023)	Philippines	The study conducted a review and analysis of maritime security initiatives and their implications on partnerships, utilizing qualitative data from interviews and document analysis					√						√	
3	(Kitada et al., 2017)	Not specified	This study used a case study methodology focusing on collaborative e-learning in maritime education, including surveys and interviews to assess the impact of e-learning platforms		√	√			√						
4	(Chadwick & Cashen, 2020)	Australia	A case study approach was employed to evaluate the advantages through industry-university collaboration in a maritime management program, using qualitative data from interviews and program assessments			√									
5	(Chen et al., 2017)	China	The study applied e-learning methodologies in maritime education and training in China, using a combination of literature review and practical applications in maritime institutions		√				√						
6	(Danylenko et al., 2021)	Not specified	The study utilized communication and information technologies and simulators to train future navigation specialists, employing both theoretical and practical training approaches						√						
7	(Dewan et al., 2023)	Malaysia	This study conducted a review of immersive and non-immersive simulators used in maritime education and training, systematically analyzing their applications and effectiveness through a systematic literature review		√	√									
8	(Frias et al., 2022)	Not specified	The study focused on the impact of education on maritime safety improvement, employing qualitative methods to analyse educational techniques and their effectiveness in improving safety competencies.											√	
9	(Galić et al., 2020)	Croatia	This study used a literature review and practical implementation to explore the use of e-learning in maritime affairs, evaluating its effectiveness in training maritime professionals		√	√			√						
10	(Gekara, 2009)	UK	The study used a qualitative research approach to understand attrition in UK maritime education and training, including interviews and surveys with maritime students and professionals												√
11	(Haapasaari et al., 2015)	Finland	A proactive approach was used in maritime safety policymaking, utilizing a combination of case studies and simulations to identify best practices in the Gulf of Finland					√						√	
12	(Helal, 2022)	Egypt	The study incorporated virtual reality into maritime safety training, using a combination of virtual simulations and competency-based learning outcomes assessments		√										
13	(IMO, 2017)	International	This document provides international standards and codes for maritime training and certification, focusing on regulatory compliance and best practices in maritime education											√	√ √

14 (T. E. Kim et al., 2021)	Rwanda	This study reviewed the continuum of simulator-based maritime training and education, analyzing various types of simulators and their pedagogical advancement	√	√	√
15 (Liu et al., 2020)	Singapore	The study conducted a pilot assessment of VR-based firefighting training in maritime contexts, using a combination of virtual reality simulations and human factors analysis	√		
16 (Magramo et al., 2009)	Not specified	The study examined the role of maritime institutions in addressing the shortage of officers, using a combination of qualitative interviews and institutional analysis			√
17 (Sharma et al., 2019)	Norway	This study rethought maritime education, training, and operations in the digital era, using a combination of literature review and case studies to explore the application of emerging immersive technologies	√		
18 (Martes, 2020)	Not specified	The study focused on best practices in competency-based education in maritime and inland navigation, using a combination of theoretical analysis and practical applications		√	
19 (Musyimi et al., 2018)	Kenya	The study examined the Belt and Road Initiative and its impact on technical and vocational education and training (TVET) in Kenya, using qualitative methods including interviews and case studies	√		
20 (Mutebi & Ferej, 2023)	Uganda	This review analyzed TVET quality assurance practices in Uganda, utilizing document analysis and qualitative interviews			√
21 (Muya Maina, 2016)	Kenya	The study assessed the relevancy of curriculum content in integrating ICTs in Kenya's TVET institutions, using a combination of surveys and qualitative analysis			√
22 (Naziz, 2019)	Bangladesh	The study proposed a model for collaboration between TVET and universities, using a combination of literature review and qualitative interviews			√
23 (Ochavillo, 2020)	Not specified	This study explored the paradigm shift in learning in maritime education amidst the COVID-19 pandemic, using surveys and interviews to analyze the effectiveness of new learning method		√	
24 (Praetorius & Sellberg, 2022)	Not specified	The study investigated strengths and weaknesses in professional marine pilot education, using qualitative methods including interviews and case study analysis			√
25 (Prayogo et al., 2022)	Not specified	This study examined maritime education in the post-COVID-19 era, using a combination of surveys and case studies to evaluate changes in educational practices		√	
26 (Rashid et al., 2009)	Malaysia	The study focused on research and development for capacity building in TVET, using a case study approach to evaluate an international PhD program			√
27 (Renganayagalu et al., 2019)	Not specified	This study investigated the impact of simulation fidelity on student self-efficacy and perceived skill development in maritime training, using a combination of surveys and comparative analysis		√	
28 (Renganayagalu et al., 2022)	Norway	The study examined maritime education and training in the COVID-19 era and beyond, using a combination of literature review and case studies to analyze the impact of the pandemic		√	
29 (Rony et al., 2019)	Not specified	The study explored new policy frameworks for environmental performance management in shipping, using a pilot study approach with qualitative data from stakeholders			√
30 (Schröder, 2019)	Not specified	This study examined regional approaches for the development of TVET systems, using qualitative methods including interviews and document analysis			√
31 (Semjonovs et al., 2015)	Not specified	The study focused on enhancing the quality of in-house training in maritime education, using a combination of surveys and interviews to assess instructor competence			√
32 (Sharma & Nazir, 2021)	Not specified	This exploratory study assessed the technology self-efficacy of maritime instructors, using surveys and qualitative interviews to analyze self-efficacy levels			√
33 (Sotiroski, 2016)	EU	The study examined the EU and international legal framework in maritime safety, using a combination of document analysis and case studies			√
34 (Tusher et al., 2023)	Not specified	The study sought best practices in assessment in maritime simulator training, using a combination of surveys and case studies		√	
35 (Vujičić et al., 2020)	Not specified	The study assessed methods for ensuring adequately qualified instructors in maritime education, using surveys and qualitative analysis			√

36 (Wang et al., 2015)	China	This study implemented a school-enterprise cooperative education model for marine practice teaching, using a combination of practical applications and theoretical analysis	√	
37 (Wärtsilä, 2020)	Not specified	The document focused on simulation and training solutions for maritime education, using document analysis and case studies to evaluate simulator effectiveness		√
38 (Zaytseva, 2016)	Not specified	The study introduced a competence-based approach in maritime training, using a combination of literature review and practical applications in educational settings		√
39 (Jamil & Bhuiyan, 2021)	United Kingdom	The study investigates the pedagogy of a marine simulation program, aiming to comprehend its profound learning components through the use of a mixed-methods approach. The study collects student perception data by means of a reflection-based survey.	√	√

CP: Curriculums and Pedagogy	CBE: Competency-Based Education
TI: Technological Integration	PF: Policy and Frameworks
IP: Industry Partnership	FR: Funding and Resources
CB: Challenges and Barriers	TD: Instructor Training and Development
SBT: Simulation-Based Training	CR: Curriculum Relevance
ELP: E-Learning Platforms	GC: Global Collaboration

4 RESULTS AND DISCUSSION

The authors presented and discussed the findings of various TVET education programs and explored their potential implementation in maritime TVET.

The study led to the findings of 3 factors, namely 1. Current state of TVET, 2. Innovation, and 3. Challenges.

However, to avoid redundancy while discussing the findings, due to the interrelated nature of the discussion points shown in Figure 1, the content is organized into two subsections: (4.1) the current state of global TVET and innovations adaptable to maritime TVET, and (4.2) challenges and opportunities.

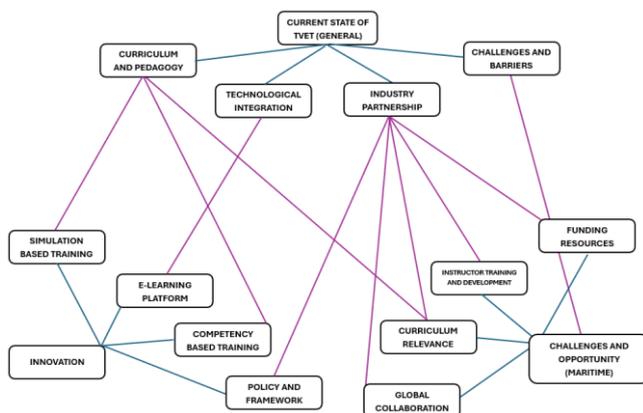


Figure 1. Relationships between subfactors for future development of maritime TVET framework

4.1 Current State of global TVET and Innovation adaptable to maritime TVET

TVET is widely recognised as a special framework designed for training an industry-ready workforce, aiming at sustainable development on a global scale. It has been utilised in various fields and was found effective to prepare students for industry to boost productivity in various regions. Its role in boosting economic growth by supplying a highly skilled workforce that caters to the demands of both local and global markets is undeniable. The strong link between post-secondary TVET participation and higher per capita income has been extensively studied, highlighting the significance of investing in vocational

education to enhance economic performance (Pavlova, 2014).

Maritime education is an area where the IMO has taken a strong stance, leading to the development of various IMO Model Courses as a reference for syllabus development for seafarers and maritime workers (IMO, 2018). It is important to highlight, while STCW focuses more on seafaring competency, ranging from support crew to management level, maritime TVET spans the whole maritime industry, including ports and terminals. These programs typically include comprehensive courses in navigation, ship operation, offshore engineering, and safety management, which are essential for preparing students for the various technical and operational roles in the maritime sector (IMO, 2018; Paryono, 2017). Such curricula ensure that graduates are well-versed in the theoretical and practical aspects necessary to operate and manage modern maritime vessels efficiently (T. E. Kim et al., 2021; Ogur, 2023).

The study acknowledges the role of the current maritime syllabus in preparing seafarers for operational duties. However, there is concern about the need for the program to be revised to remain aligned with industry needs and technological progress. In response to the needs, IMO has undertaken several initiatives, including systematically incorporating innovation into the regulatory framework. This process includes carefully balancing technology with the need to preserve safety, environmental protection, international trade facilitation, and well-being of personnel (IMO, 2025). Proactive curriculum development will not only close the gap between traditional practices and industry expectations but will also safeguard the industry's long-term resilience and sustainability (Paryono, 2017).

4.1.1 Curriculum and Pedagogy – Utilization of simulator for interactive learning

Traditional pedagogical approaches, which rely heavily on classroom-based instruction, should be supplemented by more interactive and technology-driven methods (Dewan et al., 2023; Pangen & Karki, 2021). Interactive learning is an educational approach that emphasises active student participation and engagement through dialogue, collaboration, and hands-on activities. It usually involves the use of

digital tools, multimedia, and innovative techniques, such as group projects, discussions, and problem-solving exercises. This approach is different from traditional teaching methods, where students are treated as passive recipients of the knowledge (Zhang, 2005).

A study from clinical training involving a 3-day workshop for paramedic students shows interactive simulation training led to performance increases of approximately 35% to 53.4% and confidence improvements ranging from 55.7% to 60.5%. The focus of this training was on practical scenario simulation assessments (PSSAs), where students participated in simulated emergency situations designed to replicate real-life scenarios that they might encounter in their professional roles (Carter et al., 2018).

As interactive learning encourages a pedagogical approach that actively engages students in the educational process, the IMO has also introduced its own initiatives. Under the Integrated Technical Cooperation Programme (ITCP), training plays a vital role in supporting the implementation of international maritime standards and enhancing the capacity of Member States to effectively enforce IMO instruments. Traditionally, these training activities have been delivered in person and tailored to meet the specific needs and requirements of individual countries and regions. However, given the accelerating pace of global digitalisation, particularly in teaching and virtual learning, the IMO is evolving its operational practices by adopting new digital approaches to accommodate the growing demand for online courses and to better support the global maritime industry (IMO, 2023b). Additionally, according to MSC.1/Circular.1609, interactive learning approaches via technology and video are encouraged to increase participant comprehension (IMO, 2019). These initiatives will allow the student to actively participate in the learning process through simulation and practical training and improve the retention of knowledge and skills. In addition, simulated real-world scenarios through interactive technologies like simulators and e-learning platforms greatly enhance the educational experience of maritime students (Shen et al., 2019; Youssef, 2018). The use of simulators allows students to gain hands-on augmented experience in a controlled environment, thereby enhancing their practical skills and preparedness for real-world scenarios (Nazir & Hjelmervik, 2018; Sharma et al., 2019). The combination cloud-based simulator and physical simulator has been recognised as notable progress in maritime education, offering more adaptable and efficient training options (Chen et al., 2017).

In maritime education and training, the use of simulators is more focused on ship operations. These simulators allow students to practice navigation, ship manoeuvring, engine room watchkeeping, and emergency response without the actual risks (Danylenko et al., 2021). Notably, immersive and non-immersive simulators help students develop essential seafaring skills in a safe and controlled environment, which is crucial for their competence and confidence in real-world operations (Dewan et al., 2023). In other words, simulation training allows for the rehearsal of complex and emergency scenarios that would be too dangerous or impractical to practice at sea. As an example, a study on engine room simulation training

found that students who trained with advanced simulators reported higher motivation and perceived skill development compared to those using traditional methods (Mallam et al., 2019). Another study emphasised the importance of team training via simulation, demonstrating that practice runs on sophisticated simulators could effectively prepare seafarers for emergency responses and crisis management (Baldauf et al., 2016). In another survey-based study by Jamil & Bhuiyan (2021), 112 maritime students from a UK university expressed that the simulator provided significant hands-on experience by bridging theory and practice, allowing them to better prepare for real-life scenarios. The use of high-fidelity simulators, which provide a realistic representation of maritime environments, enhances learning outcomes by improving student engagement and retention of skills (Mallam et al., 2019). This approach ensures that graduates are better prepared for the challenges they will face in their maritime careers, making them more competent and confident professionals.

4.1.2 *Technological Integration – E-Learning, Virtual Reality, smart glass*

E-learning platforms have revolutionised education by making essential training more accessible and convenient for students. These platforms support the delivery of courses and training programs virtually, allowing learners to access study materials and participate in interactive sessions from anywhere. This flexibility is particularly beneficial for seafarers who often face challenges in attending traditional classroom-based courses due to their demanding schedules and work structure (Galić et al., 2020)

An e-learning platform provides advantages not only to students and instructors but also to maritime personnel and management. Resolution MSC.349(92) and Resolution MEPC.237(65), Appendix 1 – Requirements for Training and Qualification of Recognised Organisation's Technical Staff, specify the criteria for the training and certification of technical personnel employed by recognised organisations. These standards encourage the use of remote learning and e-learning technologies to offer some components of the training. Nevertheless, a minimum of fifty percent of the overall theoretical training days must take place in a classroom setting in order to promote dialogue, deliberation, and the exchange of the instructor's expertise with the participants (IMO, 2014).

E-learning platforms offer flexible and accessible learning opportunities for maritime students. These platforms can host a variety of educational resources, including interactive modules, video lectures, and assessments (Galić et al., 2020; Popa & Cupsa, 2019; Prayogo et al., 2022). The use of e-learning platforms has been particularly beneficial during the COVID-19 pandemic, enabling continuity of education despite disruptions to traditional classroom instruction (Bolmsten et al., 2021; Chen et al., 2017; Ochavillo, 2020). According to MSC.1/Circular.1643 – Guidance on Seafarers' Training and Certification for Issuing Administrations, Flag States, and Port States During the Covid-19 Pandemic, remote training might be used to support ongoing professional development. This might be implemented through online training or e-learning, depending on the suitability of each method.

However, it may not be feasible to offer training and hands-on skill demonstrations in this manner, which should be taken into account when revalidating certifications (IMO, 2021a)

Moreover, e-learning can cater to diverse learning styles and preferences, enhancing student engagement and learning outcomes (Galić et al., 2020; Popa & Cupsa, 2019). However, the challenge is to ensure the content is aligned with the IMO requirements. According to the CTU Code—IMO/ILO/UNECE Code of Practice for Packing of Cargo Transport Units—training can be provided by external or distance e-learning providers. However, when parties enlist the help of external training providers, it is important to ensure that these providers are capable of delivering training that aligns with the requirements of the IMO (IMO, 1997).

Technological integration in TVET has gained traction, with institutions adopting virtual reality (VR) tools to enhance the learning experience. These technologies provide students with immersive and interactive learning opportunities that can replicate complex maritime operations (Chen et al., 2017; Galić et al., 2020). Additionally, online learning platforms offer flexibility and accessibility, enabling students to learn at their own pace and convenience (Popa & Cupsa, 2019).

Therefore, the integration of these advanced technologies into maritime TVET will not only improve the quality of education but also address the limitations of traditional training methods. By leveraging e-learning platforms and VR tools, maritime institutions can offer a more engaging, efficient, and flexible learning experience, better preparing students for the complexities of the maritime industry (Galić et al., 2020; Renganayagalu et al., 2022; Shen et al., 2019).

The integration of training with smart glasses has shown a significant impact on education. These devices offer students the opportunity to engage with real-time industrial scenarios, enhancing their understanding and preparedness for future employment. Smart glasses, commonly used in industrial settings, are typically worn by supervisors or technicians as seen in Figure 2, and equipped with live-streaming capabilities. This technology enables the real-time transmission of workplace operations directly to students, allowing them to observe actual industrial procedures from a remote location (Choi & Kim, 2021; Kumar et al., 2018; Romare & Skär, 2023). By witnessing these live industrial practices, students are exposed to authentic work environments and processes even before physically entering the workforce, thus bridging the gap between theoretical learning and industry practice (Abdullah et al., 2019).

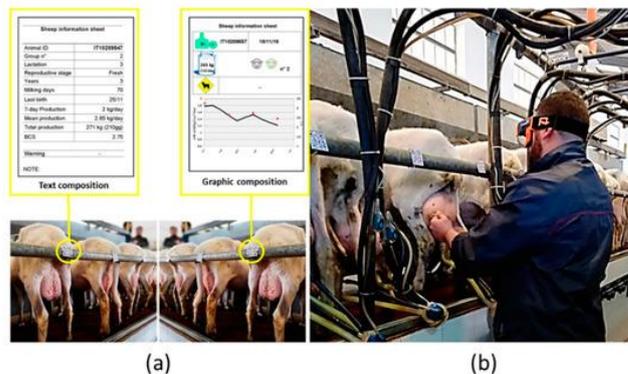


Figure 2. (a) Live information and (b) a participant milking (live video can be streamed by student) (Caria et al., 2020)

4.1.3 Industry Partnerships

Across all fields, collaboration between educational institutions and industry stakeholders was identified to be significantly important in ensuring that TVET programs are aligned with industry needs. The advantage of industry partnerships is that they can facilitate the sharing of resources, expertise, and best practices, thereby enhancing the quality and relevance of maritime TVET (Bolmsten et al., 2021; Vuletic et al., 2017). Effective collaboration between academia and industry ensures that educational programs remain relevant and up-to-date with the latest technological advancements and industry requirements. By integrating industry insights and feedback into their curricula, educational institutions can provide training that better equips students with the skills needed in the maritime sector (Bolmsten et al., 2021; Jahonga et al., 2016).

4.1.4 Competency-Based Education

Competency-based education (CBE) emphasises the development and assessment of specific skills and competencies essential for maritime professions, particularly for seafarers. This focus on skill mastery is the reason why their certification is commonly referred to as a Certificate of Competency (COC) (Demirel, 2020). CBE models emphasise practical training and real-world application, ensuring that graduates are job-ready and meet industry standards (Frias et al., 2022; Zaytseva, 2016). This approach has been shown to improve student retention and employability, as it aligns educational outcomes with industry needs (Edwin Obwoye, 2016; Martes, 2020).

CBE ensures that maritime students acquire the necessary competencies to operate effectively in their professional roles. By focusing on practical training and real-world applications, CBE prepares students to handle the specific demands and challenges of maritime professions. This hands-on approach is essential for developing the skills required for safe and efficient maritime operations (Okoye & I., 2015; Zaytseva, 2016).

Moreover, CBE has been shown to improve educational outcomes by tailoring the learning process to the specific needs of students and industry requirements. For example, CBE programs in maritime education have successfully integrated practical exercises, simulations, and real-life scenarios to enhance learning and ensure students are well-

prepared for their careers (Frias et al., 2022). This alignment with industry standards not only improves student retention but also enhances their employability by providing them with relevant and applicable skills (Edwin Obwoye, 2016).

4.1.5 Policy and Frameworks

Effective policies and frameworks are essential for supporting the development and implementation of innovative TVET programs. National and international regulatory bodies play a key role in setting standards and guidelines for maritime education and training. For example, the European Union and the International Maritime Organisation (IMO) have developed comprehensive frameworks that enhance maritime safety and environmental standards, which are critical for aligning TVET programs with industry requirements (Rony et al., 2019; Sotiroski, 2016).

These policies and frameworks must also accommodate the evolving technological advancements. For example, MSC.1/Circ.1638—Outcome of the Regulatory Scoping Exercise for the Use of Maritime Autonomous Surface Ships (MASS)—emphasizes the importance of developing policies and frameworks that support new policy for training (IMO, 2021b).

Collaborative efforts between governments, educational institutions, and industry stakeholders can facilitate the sharing of resources and best practices, thereby enhancing the quality and relevance of maritime TVET. Such partnerships are crucial for the continuous improvement of TVET programs to meet the evolving demands of the maritime industry. For instance, initiatives in the Gulf of Finland have demonstrated the effectiveness of regional collaboration in developing proactive maritime safety policies that involve multiple stakeholders in the decision-making process (Haapasaari et al., 2015).

Moreover, frameworks like the Technical and Vocational Education and Training (TVET) systems in Uganda emphasise the importance of a coordinated approach to policy implementation, quality assurance, and governance to ensure that TVET programs produce graduates who meet industry standards (Mutebi & Ferej, 2023).

The study discovers the urgent need for the government to broaden the entry requirements for maritime education programs. In 2023, the Malaysia Marine Department (MMD) took a significant step by revising the entry standards for the combined diploma and preparatory course for Officer in Charge of Navigational Watch more than 500 GT and Officer in Charge of Engineering Watch more than 750 kW unlimited voyage. Previously, these programs were only accessible to students who achieved five credits in the Sijil Pelajaran Malaysia (SPM). However, the revised policy now allows Technical and Vocational Education and Training (TVET) graduates, such as those holding the Sijil Vokasional Malaysia (SVM) and Sijil Kemahiran Malaysia (SKM), to enrol, even if they did not sit for the SPM examination (MMD, 2023).

This initiative is very well-timed and necessary. Seafaring is a career that demands strong hands-on competencies, and TVET institutions are better positioned to produce graduates with practical skills,

work ethics, and technical know-how essential for such roles. In contrast, SPM students may be prone towards academic pathways, and many lack interest in the physically demanding, skill-intensive nature of maritime work. As such, relying solely on academically inclined SPM graduates as the talent pipeline for maritime professions risks further decline in enrolment and long-term workforce shortages.

To ensure a sustainable and inclusive maritime workforce, this initiative by MMD should be adopted across other accreditation frameworks as well. Currently, entry into foundation programs, an essential steppingstone towards bachelor's degrees, still requires five SPM credits. This prerequisite effectively bars many capable TVET graduates from progressing to higher education, thus limiting their career advancement opportunities in the maritime sector.

Therefore, the study strongly recommends a comprehensive policy revision. The existing frameworks, though well-intentioned, may unintentionally exclude qualified and motivated individuals from maritime careers. By realigning entry requirements to reflect the practical nature of maritime training and by recognising the value of TVET pathways, Malaysia can ensure a more inclusive, diversified, and competent maritime workforce in the years to come.

4.2 Challenges and Opportunities in Maritime TVET

Despite the advancements, TVET faces several challenges. Funding constraints and limited access to modern training facilities can restrict the implementation of innovative teaching methods and technologies. For instance, in many countries, the fragmented financing systems and high costs of TVET programs lead to inadequate budgetary allocations, making it difficult for institutions to provide quality education and training (Hondonga & Ramaligela, 2019). In Nigeria, although the government has allocated funds to TVET, the distribution of these funds is often inefficient, which affects the overall effectiveness of TVET programs (Osidiye, 2019).

The shortage of qualified instructors with both industry experience and pedagogical expertise significantly impacts the quality of education. Particularly in the maritime sector, there is an emphasis on the need for instructors to be not only proficient in their technical fields but also skilled in educational methodologies (MMD, 2017). Studies have identified the lack of organisational support and pedagogical training as factors that may diminish the effectiveness of maritime education (Sellberg, 2018).

4.2.1 Funding and Resources

Adequate funding and resources are critical for the successful implementation of maritime TVET programs. Literature emphasises the role of financial support in ensuring quality TVET education. Funding from various sources, including government bodies, industry partners, and international organisations, is essential to overcoming financial constraints and enhancing the quality of training facilities and technologies (Amoamah et al., 2017; Osidiye, 2019). However, many institutions face financial constraints

that limit their ability to invest in modern training facilities and technologies. These financial limitations hinder the effective delivery of TVET programs and their ability to meet industry standards (Chinyere Shirley et al., 2015; Edokpolor & Dumbiri, 2019).

4.2.1.1 Institution-industry collaboration

One of the key findings for technology issues discovered in this study was the lack of collaboration between universities and maritime sectors, which has resulted in a talent deficit in the industry (Rauf et al., 2023). Therefore, to ensure the future competitiveness of the industry in post-pandemic times, the collaboration between the university and the industry is crucial (Vacondio et al., 2021). Moreover, internships and apprenticeships provide students with valuable hands-on experience and exposure to real-world operations (Chadwick & Cashen, 2020; Wang et al., 2015).

This issue can be resolved by strengthening the relationship between the industry and educational institutions. Taking examples across other fields, the collaboration between educational institutions in Malaysia with multinational companies such as Intel and Motorola Solutions has led to the establishment of 129 MakerLabs in schools that significantly benefited both the local population and the country. These MakerLabs equip students with essential technical skills like coding and 3D design. This initiative enhances students' innovation, critical thinking, and problem-solving abilities, preparing them for the future workforce. Additionally, it strengthens Penang's position as a leader in education and technological advancement in Malaysia (Citizen Journal, 2024).

Therefore, collaborative networks within the maritime sector can help in resource optimisation and knowledge exchange, fostering an environment where best practices can be shared and implemented across institutions and companies (Naziz, 2019; Vuletic et al., 2017). Such partnerships are instrumental in developing comprehensive training programs that cover both theoretical knowledge and practical skills.

Internships and apprenticeships are integral components of this collaborative approach; having industries offer students hands-on experience that is invaluable for their professional development is crucial (Chadwick & Cashen, 2020; Musyimi et al., 2018). With industry and university collaboration, the student will be able to get placement as early as possible to ensure their career growth is not delayed. This practical exposure not only enhances their learning experience but also increases their employability upon graduation.

4.2.1.2 Government fund

Securing funding from government bodies, industry partners, and international organisations is essential for supporting the growth and development of maritime TVET. Effective strategies for funding include public-private partnerships, donations, and leveraging international aid to support TVET infrastructure and program quality (Bhattarai et al., 2021).

In Malaysia, for example, the government offers a variety of funding opportunities aimed at fostering innovation. One of the examples, the Applied Innovation Fund (AIF) provided by the Malaysia Ministry of Science, Technology, and Innovation (MOSTI), supports various fields of innovation and is open to individuals, including youth, single mothers, and persons with disabilities. This fund is also available to start-up companies, SMEs, higher education institutions, government research institutes (GRI), associations, cooperatives, and registered NGOs. In addition, MOSTI offers other funding programs such as Technology Development 1 (TeD1), Technology Development 2 (TeD2), Bridging Grant Fund, and strategic research funds through implementing and monitoring agencies (SRF-APP) at various levels of research and development (MOSTI, 2024).

4.2.1.3 Establishment of national strategic plan

The integration of TVET into the national strategic plan in the Americas has played a crucial role in driving economic growth, improving workforce skills, and reducing unemployment, particularly in developing countries. In Guyana and several Latin American nations, the alignment of TVET with broader national goals, such as poverty reduction, social inclusion, and sustainable economic development, has been particularly impactful. In Guyana, TVET has been central to efforts to diversify the economy beyond traditional sectors like agriculture and mining. This has been supported by international organisations like the United Nations Development Programme (UNDP), which have facilitated the development of TVET programs tailored to the needs of the labour market, enhancing employability and supporting economic resilience (Paryono, 2017; Prada et al., 2023).

Similarly, in Latin American countries, TVET integration has been supported by international organisations and regional bodies, focusing on improving education quality, aligning training with market demands, and fostering partnerships between governments, the private sector, and educational institutions (Dixon & Hutton, 2016; Velázquez Gomar, 2014). The UNDP and other agencies have supported modernising TVET curricula, improving teacher training, and expanding access to vocational education for marginalised communities, addressing the skills gap and promoting social mobility.

As a result, the involvement of international organisations like the UNDP has brought global best practices and funding to the region, enabling countries to develop more effective and inclusive TVET systems. This has included promoting gender equality in vocational training, integrating digital skills into TVET programs, and fostering public-private partnerships to ensure training relevance to industry needs (Urquidi, 2004).

4.2.2 Instructor Training and Development

Many institutions struggle to find instructors who not only understand the theoretical aspects of maritime training but also have practical, hands-on experience in the industry. This gap results in a mismatch between the skills taught and the skills required by the industry, ultimately affecting the employability of graduates

(Lamichhane, 2016). In Nigeria, the need for enhanced educational technology in technical schools is critical to expose students to relevant knowledge and skills required in the modern workforce, but this need is often unmet due to funding and resource limitations (Aniah & Mohammed, 2021).

Addressing these challenges requires a concerted effort from policymakers, educators, and industry stakeholders to invest in and support maritime TVET. A sustainable financing mechanism is crucial for better TVET service delivery. For example, in Nepal, TVET financing has been influenced by various factors, including the national economy and the engagement of the private sector. Despite budget allocations, the actual funds provided are often insufficient to achieve significant improvements in TVET quality and accessibility (Aryal, 2020). Similarly, in Nigeria, effective strategies for funding TVET programs include public-private partnerships, donations, and skill development levies, which could help bridge the gap in funding and resource allocation (Oviawe, 2020).

Ensuring that maritime instructors are adequately qualified involves meeting the standards set by international conventions and continuously updating their competencies to align with industry advancements (Semjonovs et al., 2015; Vujičić et al., 2020). In Malaysia, one of the requirements for maintaining status as a TVET provider is that instructors must complete an industrial attachment (MQA & JPK, 2021). According to the notification letter MQA.100-1/7/2 JLD 3 (20), the TVET Standard states that all teaching staff in service at TVET providers are required to participate in industrial attachment training for a cumulative period of one month every two years (MQA, 2021; MQA & JPK, 2021). Industrial attachment allows for the instructors to be up-to-date with the industry advancement and latest regulatory requirements. Continuous professional development is crucial for maintaining high standards of maritime education and training (W. Kim et al., 2019; Sharma et al., 2019).

To effectively address the ongoing challenge of attracting and retaining qualified instructors, it is crucial to implement a multifaceted approach that not only focuses on competitive salaries but also addresses other significant factors. Offering competitive salaries is a fundamental step, as financial incentives play a critical role in attracting talent (Estimo, 2020). However, salary alone is not sufficient to ensure long-term retention. Frederick Herzberg's Two-Factor Theory (1959) posits that job satisfaction and dissatisfaction arise from two distinct categories: motivators, which are intrinsic factors such as achievement, recognition, responsibility, personal growth, and the nature of the work itself; and hygiene factors, which are extrinsic elements including salary, supervision, company policy, working conditions, job security, and interpersonal relations (Alrawahi et al., 2020; House & Wigdor, 1967).

Therefore, providing opportunities for career advancement is equally important. Instructors are more likely to stay committed to an organisation if they see clear pathways for professional growth. This can include access to continuing education, leadership training programs, and opportunities for research and innovation within their field. Such initiatives not only

enhance the skills of the instructors but also contribute to their sense of fulfilment and professional satisfaction (Kosyrev et al., 2009).

Creating a supportive working environment is another crucial factor. This includes fostering a culture of collaboration, providing access to modern teaching tools and technologies, and ensuring manageable workloads. Supportive environments also involve recognising and addressing the unique challenges that instructors face, such as balancing teaching responsibilities with industry engagement and professional development. Research has shown that when educators feel supported by their institutions, they are more likely to remain in their positions and contribute positively to the educational outcomes (Praetorius & Sellberg, 2022).

Moreover, offering flexibility in work arrangements, such as allowing part-time positions or sabbaticals for industry experience, can further enhance retention. These strategies enable instructors to stay current with industry trends, which in turn enriches the learning experience for students and keeps the educators engaged and motivated in their roles (Estimo, 2020).

In summary, while competitive salaries are a key element, they must be complemented by career development opportunities and supportive working environments to effectively attract and retain skilled instructors in the long term.

4.2.3 Curriculum Relevance and Adaptability

Ensuring that maritime TVET curricula remain relevant and adaptable to industry changes is crucial for preparing students for the workforce. Regular curriculum reviews and updates, informed by industry feedback and technological advancements, help align educational programs with current and future industry needs. This alignment is essential to keep the curricula up-to-date with the dynamic nature of the maritime sector and its technological progress (Muya Maina, 2016; Pavlova, 2019).

Moreover, incorporating flexible and modular course structures can allow students to tailor their education to specific career goals and interests. This approach not only caters to individual student needs but also enhances the adaptability of the curriculum to meet various industry requirements. Such modular structures enable institutions to offer specialised training that aligns with specific industry demands, thereby improving employability (Huisinga, 2009; Schröder, 2019).

4.2.4 Global Collaboration

Global collaboration and standardisation are key to ensuring the quality and consistency of maritime TVET across different regions. International partnerships and exchanges can facilitate the sharing of knowledge, resources, and best practices, thereby enhancing the overall quality of maritime education. Such collaboration is essential to address the challenges posed by globalisation and technological changes, ensuring that TVET remains relevant and effective (Dambudzo, 2013; Naziz, 2019).

In Asia, the collaboration between institutions such as the Maritime Academy of Asia and the Pacific (MAAP) and international partners highlights the importance of funded partnerships to enhance maritime security training and capacity building (Baylon & Santos, 2023). Similarly, initiatives in Malaysia and other Southeast Asian countries demonstrate the role of international cooperation and funding in developing robust TVET programs (Rashid et al., 2009; Schröder, 2019).

Standardisation of certification and accreditation processes can also ensure that maritime professionals are equipped with the skills and competencies required by the global maritime industry (IMO, 2018). Additionally, the development of international standards, such as those by ISO, plays a crucial role in creating a unified framework for maritime education and training, promoting interoperability, and ensuring that qualifications are recognised globally (Đurić, 2023).

5 CONCLUSION

The evolution of maritime Technical and Vocational Education and Training (TVET) is essential to meet the growing demands of the global maritime sector, which is being reshaped by technological innovation, regulatory shifts, and the digital transformation of shipping and port operations. This review highlights that, while maritime TVET frameworks have made significant progress, particularly through the integration of simulators, e-learning, and competency-based education. Critical challenges remain in aligning curricula with industry needs, strengthening industry-education partnerships, and addressing persistent gaps in funding, instructor qualifications, and infrastructure.

Simulation-based and digital learning methods have been proven effective in enhancing practical skills and student engagement, but their successful implementation depends on the continuous modernization of curricula and regular upskilling of instructors. Expanding access to maritime programs by broadening entry requirements, especially for TVET graduates, is vital to ensuring a steady and diverse talent pipeline for the maritime industry. Similarly, policy reforms are needed to support inclusive pathways from vocational to higher education and to recognize the value of hands-on, skills-based training.

Despite advancements, financial constraints, limited resources, and a shortage of industry-experienced instructors continue to hinder progress. Addressing these challenges requires sustained government and industry investment, effective public-private partnerships, and the creation of national strategic plans that integrate TVET into broader economic and workforce development strategies.

Global collaboration, standardization of qualifications, and sharing of best practices are crucial for maintaining the relevance and quality of maritime TVET worldwide. Ultimately, the review underscores the need for a flexible, responsive, and industry-aligned TVET system, supported by robust policy frameworks, stakeholder collaboration, and targeted investment, to prepare maritime professionals who are

adaptable, innovative, and equipped to drive the sector's sustainable growth.

FUNDING

This work was supported by Universiti Malaysia Terengganu under grant TAPERG/2025/UMT/6053.

REFERENCES

- Abdullah, S. A., Saud, M. S., & Kamin, Y. (2019). M-learning for technical and vocational education training (TVET). *International Journal of Recent Technology and Engineering*, 8(3), 7236–7239. <https://doi.org/10.35940/ijrte.C6291.098319>
- ALAM. (2019). Deck Ratings - ALAM. <https://www.alam.edu.my/courses/deck-ratings/>
- Alrawahi, S., Sellgren, S. F., Altouby, S., Alwahaibi, N., & Brommels, M. (2020). The application of Herzberg's two-factor theory of motivation to job satisfaction in clinical laboratories in Omani hospitals. *Heliyon*, 6(9), e04829. <https://doi.org/10.1016/j.heliyon.2020.e04829>
- Amoamah, M. O., Ndom, E., Ampiaiw, R. E., & Dadzie, J. (2017). Funding of Quality TVET Programmes in Tertiary Institutions: The Role of Business Development Units. *Journal of Economics and Sustainable Development*, 8(22).
- Aniah, A., & Mohammed, A. (2021). Challenges of technical vocational education and training (TVET) and the need for enhanced educational technology in technical schools in Nigeria. *Integrity Journal of Education and Training*, 5(2), 23–27. <https://doi.org/10.31248/IJET2021.103>
- Aryal, B. P. (2020). Financing of Technical and Vocational Education and Training in Nepal. *Journal of Education and Research*, 10(1). <https://doi.org/10.3126/jer.v10i1.31898>
- Baldauf, M., Dalaklis, D., & Kataria, A. (2016). TEAM TRAINING IN SAFETY AND SECURITY VIA SIMULATION: A PRACTICAL DIMENSION OF MARITIME EDUCATION AND TRAINING. *INTED2016 Proceedings*, 1. <https://doi.org/10.21125/inted.2016.0983>
- Baldauf, M., & Hong, S.-B. (2016). Improving and Assessing the Impact of e-Navigation applications. *International Journal of E-Navigation and Maritime Economy*, 4, 1–12. <https://doi.org/10.1016/j.enavi.2016.06.001>
- Bartusevičienė, I., & Valionienė, E. (2021). An integrative approach for digitalization challenges of the future maritime specialists: A case study of the Lithuanian maritime academy. *TransNav*, 15(2). <https://doi.org/10.12716/1001.15.02.11>
- Baylon, A., & Santos, E. (2023). Maritime Security Initiatives at Maap: Implications for a Ched-Funded Partnership with the University of Wollongong Australia. *Pedagogika-Pedagogy*, 95(6s), 56–63. <https://doi.org/10.53656/ped2023-6s.06>
- Bhattarai, P. C., Baral, D. P., & Paudel, P. K. (2021). Technical and Vocational Education and Training Fund in Nepal: Present Practice and Way Forward. *Journal of Training and Development*, 6(01). <https://doi.org/10.3126/jtd.v6i01.41778>
- Bolmsten, J., Manuel, M. E., Kaizer, A., Kasepöld, K., Sköld, D., & Ziemka, M. (2021). Educating the Global Maritime Professional—a case of collaborative e-learning. *WMU Journal of Maritime Affairs*, 20(3). <https://doi.org/10.1007/s13437-020-00224-w>
- Caria, M., Todde, G., Sara, G., Piras, M., & Pazzona, A. (2020). Performance and usability of smartglasses for augmented reality in precision livestock farming operations. *Applied Sciences (Switzerland)*, 10(7). <https://doi.org/10.3390/app10072318>

- Carter, O. B. J., Mills, B. W., & Ross, N. P. (2018). Correction: Assessing simulation-based clinical training: Comparing the concurrent validity of students' self-reported satisfaction and confidence measures against objective clinical examinations. *BMJ Simulation and Technology Enhanced Learning*, 4(3). <https://doi.org/10.1136/bmjstel-2015-000089corr1>
- Catalin, P. (2013). THE E-LEARNING PARTICULARITIES FOR MARITIME TRAINING AND EDUCATION. STUDY CASE ON TRAINING SIMULATOR FOR INTEGRATED SHIP MANAGEMENT. 9th International Conference ELearning and Software for Education, 2. <https://doi.org/10.12753/2066-026x-13-148>
- Chadwick, K., & Cashen, L. (2020). The 'berth' of a maritime management program: A case study on value creation through industry–university collaboration. *Industry and Higher Education*, 34(2). <https://doi.org/10.1177/0950422219885866>
- Chen, X., Bai, X., & Xiao, Y. (2017). The Application of E-learning in Maritime Education and Training in China. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, 11(2). <https://doi.org/10.12716/1001.11.02.19>
- Chinyere Shirley, A., Chijioko, O. P., & Benjamin Chukwumaijem, O. (2015). Towards Quality Technical Vocational Education and Training (Tvet) Programmes in Nigeria: Challenges and Improvement Strategies. *Journal of Education and Learning*, 4(1). <https://doi.org/10.5539/jel.v4n1p25>
- Choi, Y., & Kim, Y. (2021). Applications of smart helmet in applied sciences: A systematic review. *Applied Sciences (Switzerland)*, 11(11). <https://doi.org/10.3390/app11115039>
- Citizen Journal. (2024). Penang leads the way with 129 MakerLabs in schools. <https://cj.my/146608/penang-leads-the-way-with-129-makerlabs-in-schools/>
- Dambudzo, I. I. (2013). Collaboration in the Integration of Academic and TVET through ODL and Industry: Strategies, Challenges and Opportunities. *Greener Journal of Social Sciences*, 3(9), 423–433. <https://doi.org/10.15580/GJSS.2013.9.280913867>
- Danylenko, O. B., Soroka, O. M., Dukov, D. F., Soshnikov, S. G., & Kramarenko, V. V. (2021). Application of information and communication technologies and simulators to train future specialists in navigation and ship handling. *IOP Conference Series: Materials Science and Engineering*, 1031(1). <https://doi.org/10.1088/1757-899X/1031/1/012117>
- Demirel, E. (2020). Maritime Education and Training in the Digital Era. *Universal Journal of Educational Research*, 8(9), 4129–4142. <https://doi.org/10.13189/ujer.2020.080939>
- Dewan, M. H., Godina, R., Chowdhury, M. R. K., Noor, C. W. M., Wan Nik, W. M. N., & Man, M. (2023). Immersive and Non-Immersive Simulators for the Education and Training in Maritime Domain—A Review. *Journal of Marine Science and Engineering*, 11(1). <https://doi.org/10.3390/jmse11010147>
- Dixon, R. A., & Hutton, D. M. (2016). STEM And TVET In The Caribbean A Framework for Integration at the Primary, Secondary, and Tertiary Levels. *Caribbean Curriculum*, 24.
- Đurić, M. (2023). Development of international standards for university-business collaboration. 371–381. <https://doi.org/10.24094/ptk.023.371>
- Edokpolor, J. E., & Dumbiri, D. N. (2019). RESOURCE ADEQUACY AND UTILIZATION FOR TEACHING AND LEARNING EFFECTIVENESS IN VOCATIONAL EDUCATION PROGRAMMES IN SOUTH-SOUTH NIGERIAN UNIVERSITIES. *Journal of Vocational Education Studies*, 2(1). <https://doi.org/10.12928/joves.v2i1.727>
- Edwin Obwoye, M. (2016). Competency Based Education and Training: A Fresh Green Leaf from the Australian Context for TVET in Africa. *IRA International Journal of Education and Multidisciplinary Studies (ISSN 2455–2526)*, 3(3). <https://doi.org/10.21013/jems.v3.n3.p23>
- Estimo, E. (2020). Ship to Academe, Seafaring to Teaching: Seafarer Teachers in Maritime Higher Education Institutions in the Philippines. *Higher Education Research*, 5(2). <https://doi.org/10.11648/j.her.20200502.12>
- Frias, A., Águia, P., & Simões-Marques, M. (2022). Education as a maritime safety improvement factor. *Human Factors and Systems Interaction*, 52. <https://doi.org/10.54941/ahfe1002134>
- Galić, S., Lušić, Z., & Stanivuk, T. (2020). E-learning in maritime affairs. *Journal of Naval Architecture and Marine Engineering*, 17(1). <https://doi.org/10.3329/jname.v17i1.42203>
- Gekara, V. (2009). Understanding attrition in UK maritime education and training. *Globalisation, Societies and Education*, 7(2). <https://doi.org/10.1080/14767720902908190>
- Haapasaari, P., Helle, I., Lehtikoinen, A., Lappalainen, J., & Kuikka, S. (2015). A proactive approach for maritime safety policy making for the Gulf of Finland: Seeking best practices. *Marine Policy*, 60. <https://doi.org/10.1016/j.marpol.2015.06.003>
- Helal, H. (2022). Incorporating virtual reality into maritime safety training to enhance competency-based learning outcomes. <https://doi.org/10.5821/mt.11414>
- Hondonga, J., & Ramaligela, S. M. (2019). Comparing Financing Models for Vocational Education and Training in Botswana, South Africa, and Zimbabwe. <https://doi.org/10.4018/978-1-5225-4145-5.ch003>
- House, R. J., & Wigdor, L. A. (1967). Herzberg's Dual-Factor Theory Of Job Satisfaction And Motivation: A Review Of The Evidence And A Criticism. 369–388.
- Huisinga, R. (2009). Approaches to Designing TVET Curricula. In *International Handbook of Education for the Changing World of Work* (pp. 1669–1686). Springer Netherlands. https://doi.org/10.1007/978-1-4020-5281-1_112
- IMO. (1997). CTU Code - IMO/ILO/UNECE Code of Practice for Packing of Cargo Transport Units.
- IMO. (2014). RESOLUTION MSC.349(92) (Adopted on 21 June 2013) CODE FOR RECOGNIZED ORGANIZATIONS (RO CODE).
- IMO. (2017). Res.A. 788(18) - Revised Guidelines on the Implementation of the International Safety Management Code by Administrations. 1118(December), 2017–2019.
- IMO. (2018). STCW : including 2010 Manila amendments : STCW Convention and STCW Code: International Convention on Standards of Training, Certification and Watchkeeping for Seafarers. [http://www.imo.org/en/about/conventions/listofconventions/pages/international-convention-on-standards-of-training,-certification-and-watchkeeping-for-seafarers-\(stcw\).aspx](http://www.imo.org/en/about/conventions/listofconventions/pages/international-convention-on-standards-of-training,-certification-and-watchkeeping-for-seafarers-(stcw).aspx)
- IMO. (2019). I:\CIRC\MSC\01\MSC.1-Circ.1609.docx. [https://www.crclass.org/chinese/download/ti-tc/106/1-2 MSC.1-Circ.1609 - Guidelines For The Standardization Of User Interface Design For Navigation Equipment \(Secretariat\) \(1\).pdf](https://www.crclass.org/chinese/download/ti-tc/106/1-2 MSC.1-Circ.1609 - Guidelines For The Standardization Of User Interface Design For Navigation Equipment (Secretariat) (1).pdf)
- IMO. (2021a). Guidance on Seafarers' Training and Certification for Issuing Administrations, Flag States and Port States During the Covid-19 Pandemic.
- IMO. (2021b). Outcome of the Regulatory Scoping Exercise for the Use of Maritime Autonomous Surface Ships (Mass). MSC.1/Circ.1638. [https://www.wcdn.imo.org/localresources/en/MediaCentre/PressBriefings/Documents/MS.1-Circ.1638 - Outcome Of The Regulatory Scoping Exercise For The Use Of Maritime Autonomous Surface Ships... \(Secretariat\).pdf](https://www.wcdn.imo.org/localresources/en/MediaCentre/PressBriefings/Documents/MS.1-Circ.1638 - Outcome Of The Regulatory Scoping Exercise For The Use Of Maritime Autonomous Surface Ships... (Secretariat).pdf)
- IMO. (2023a). 2023 IMO STRATEGY ON REDUCTION OF GHG EMISSIONS FROM SHIPS.
- IMO. (2023b). IMO e-Learning and Training. <https://www.imo.org/en/ourwork/technicalcooperation/pages/imoee-learning.aspx>

- IMO. (2025). Autonomous shipping. https://www.imo.org/en/mediacentre/hottopics/pages/autonomous-shipping.aspx?utm_source=chatgpt.com
- Jahonga, W. M., Canute, B., Murey, E. J., Otunga, C., Kiprop, D. C., & Z, D. K. (2016). Collaborative and Linkage Programs Between TVET Institutions and the Industry. A Case of TVET Institutions in North Rift Region, Kenya. *IOSR Journal of Economics and Finance*, 07(04). <https://doi.org/10.9790/5933-0704040105>
- Jamil, M. G., & Bhuiyan, Z. (2021). Deep learning elements in maritime simulation programmes: a pedagogical exploration of learner experiences. *International Journal of Educational Technology in Higher Education*, 18(1). <https://doi.org/10.1186/s41239-021-00255-0>
- Kim, T. E., Sharma, A., Bustgaard, M., Gyldensten, W. C., Nymoen, O. K., Tusher, H. M., & Nazir, S. (2021). The continuum of simulator-based maritime training and education. *WMU Journal of Maritime Affairs*, 20(2). <https://doi.org/10.1007/s13437-021-00242-2>
- Kim, W., Shin, H. Y., Woo, H., & Kim, J. (2019). Further training needs for TVET trainers: Lessons from a national survey on rwandan TVET trainers' instructional competencies. *Journal of Technical Education and Training*, 11(2). <https://doi.org/10.30880/jtet.2019.11.02.004>
- Kitada, M., Bolmsten, J., Zeya, K., Hieu Pham, T., & Aung, M. S. (2017). Learning theories meet virtual classroom technologies: Understanding new educational opportunities in maritime education and training. 18th Annual General Assembly of the International Association of Maritime Universities - Global Perspectives in MET: Towards Sustainable, Green and Integrated Maritime Transport, IAMU 2017, 1, 72–81.
- Kosyrev, V. P., Kubrushko, P. F., & Kouznetsov, A. N. (2009). TVET Teacher-Training Requirements in the Russian Federation. In *International Handbook of Education for the Changing World of Work*. https://doi.org/10.1007/978-1-4020-5281-1_80
- Kumar, N. M., Kumar Singh, N., & Peddiny, V. K. (2018). Wearable smart glass: Features, applications, current progress and challenges. *Proceedings of the 2nd International Conference on Green Computing and Internet of Things, ICGCIoT 2018, August*, 577–582. <https://doi.org/10.1109/ICGCIoT.2018.8753047>
- Lamichhane, R. (2016). Challenges of Sustainable Development of TVET Programs and Projects. *Journal of Training and Development*, 2. <https://doi.org/10.3126/jtd.v2i0.15431>
- Liu, Y., Lan, Z., Tschoerner, B., Viridi, S. S., Cui, J., Li, F., Sourina, O., Zhang, D., Chai, D., & Muller-Wittig, W. (2020). Human Factors Assessment in VR-based Firefighting Training in Maritime: A Pilot Study. *Proceedings - 2020 International Conference on Cyberworlds, CW 2020*. <https://doi.org/10.1109/CW49994.2020.00034>
- Magramo, M., Bernas, L., Calambuhay, J., & Eler, G. (2009). The role of the maritime institutions on the shortage of officers. *Marine Navigation and Safety of Sea Transportation*. <https://doi.org/10.1201/9780203869345-135>
- Mallam, S. C., Nazir, S., & Renganayagalu, S. K. (2019). Rethinking maritime education, training, and operations in the digital era: Applications for emerging immersive technologies. In *Journal of Marine Science and Engineering* (Vol. 7, Issue 12). <https://doi.org/10.3390/JMSE7120428>
- Martes, L. (2020). Best practices in competency-based education in maritime and inland navigation. *TransNav*, 14(3). <https://doi.org/10.12716/1001.14.03.06>
- MMD. (2017). Guideline for Maritime Training Institute & Courses Accreditation. http://www.marine.gov.my/jlmeng/pic/article/BI_new_updated.pdf
- MMD. (2023). Penyeragaman syarat kemasukan minimum bagi semua kursus persediaan utama perakuan kekompetenan pelaut.
- MOSTI. (2024). Fund Division. <https://www.mosti.gov.my/en/bahagian-dana/>
- MQA. (2021). Surat Makluman MQA Bil. 1 2021 - Transisi Standard TVET dalam COPTPA.
- MQA, & JPK. (2021). CODE OF PRACTICE FOR TVET PROGRAMME ACCREDITATION, COPTPA (Second Edition).
- Musyimi, C. M., Malechwanz, J., & Luo, H. (2018). The Belt and Road Initiative and Technical and Vocational Education and Training (TVET) in Kenya: The Kenya-China TVET Project. *Frontiers of Education in China*, 13(3). <https://doi.org/10.1007/s11516-018-0017-x>
- Mutebi, R., & Ferej, A. (2023). A Review of TVET Quality Assurance Practice in Uganda. *East African Journal of Interdisciplinary Studies*, 6(1). <https://doi.org/10.37284/eajis.6.1.1327>
- Muya Maina, T. (2016). Curriculum Content Relevancy in Integration of ICTs in Kenya TVET Institutions in Readiness to Industry Needs. *International Journal of Secondary Education*, 4(6). <https://doi.org/10.11648/j.ijsedu.20160406.11>
- Nazir, S., & Hjelmervik, K. (2018). Advance use of training simulator in maritime education and training: A questionnaire study. *Advances in Intelligent Systems and Computing*, 596. https://doi.org/10.1007/978-3-319-60018-5_35
- Nazir, S., Øvergård, K. I., & Yang, Z. (2015). Towards Effective Training for Process and Maritime Industries. *Procedia Manufacturing*, 3. <https://doi.org/10.1016/j.promfg.2015.07.409>
- Nazir, A. (2019). Collaboration for transition between TVET and university: a proposal. *International Journal of Sustainability in Higher Education*, 20(8). <https://doi.org/10.1108/IJSHE-10-2018-0197>
- Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic Analysis: Striving to Meet the Trustworthiness Criteria. *International Journal of Qualitative Methods*, 16(1), 1–13. <https://doi.org/10.1177/1609406917733847>
- Ochavillo, G. S. (2020). A Paradigm Shift of Learning in Maritime Education amidst COVID-19 Pandemic. *International Journal of Higher Education*, 9(6). <https://doi.org/10.5430/ijhe.v9n6p164>
- Ogur, E. O. (2023). TVET, economy and sustainable development. *International Journal of Vocational and Technical Education*, 15(2). <https://doi.org/10.5897/ijvte2022.0315>
- Okoye, K. R., & I, M. O. (2015). Enhancing Technical and Vocational Education and Training (TVET) in Nigeria for Sustainable Development: Competency-Based Training (CBT) Approach. *Journal of Education and Practice*, 6(29).
- Osidiye, A. (2019). Funding Effectiveness of TVET for Decent Employment and Inclusive Growth in Nigeria with Perspectives from China. *Journal of Education and Practice*. <https://doi.org/10.7176/JEP/10-36-06>
- Oviawe, J. I. (2020). Strategies for funding technical vocational education and training for achieving sustainable national development in Nigeria in a post-oil boom economy. *Vietnam Journal of Education*, 4(2). <https://doi.org/10.52296/vje.2020.13>
- Pangeni, S. K., & Karki, G. (2021). E-Learning Initiatives at CTEVT: An Attempt at Innovation and Paradigm Shift in TVET Pedagogy. *Journal of Technical and Vocational Education and Training*, 1(15). <https://doi.org/10.3126/tvet.v1i15.45175>
- Paryono. (2017). The importance of TVET and its contribution to sustainable development. *AIP Conference Proceedings*, 1887. <https://doi.org/10.1063/1.5003559>
- Pavlova, M. (2014). TVET as an important factor in country's economic development. *SpringerPlus*, 3(1). <https://doi.org/10.1186/2193-1801-3-S1-K3>

- Pavlova, M. (2019). Emerging environmental industries: impact on required skills and TVET systems. *International Journal of Training Research*, 17(sup1). <https://doi.org/10.1080/14480220.2019.1639276>
- Popa, T., & Cupsa, O. S. (2019). E-LEARNING PLATFORMS – NEW SOLUTION FOR CONTINUOUS TRAINING OF ADULTS. *EDULEARN19 Proceedings*, 1. <https://doi.org/10.21125/edulearn.2019.0848>
- Prada, M. F., Carmona, L., Casas, L., Eckardt, M., García, C., Luengo, D., & Saavedra, F. (2023). SKILLS FOR WORK IN LATIN AMERICA AND THE CARIBBEAN UNLOCKING TALENT FOR A SUSTAINABLE AND EQUITABLE FUTURE. www.iadb.org
- Praetorius, G., & Sellberg, C. (2022). Exploring strengths and weaknesses in professional marine pilot education. *Human Factors in Transportation*, 60. <https://doi.org/10.54941/ahfe1002502>
- Prayogo, D., Supendi, Antoro, D., Huda, S., Fitriyaningsih, A., Surjaman, F., Purwantono, Choeroni, M., & Sugiyarto. (2022). Maritime Education after COVID-19 Era. *TransNav*, 16(2). <https://doi.org/10.12716/1001.16.02.04>
- Rashid, J., Noor, W. M., & Syarizul, M. (2009). Research and development for capacity building in TVET: the international PhD programme between UTHM And ITB Germany. *Journal of Technical Education and Training*, 1(1).
- Rauf, U. A. A., Aziz, N. I., Zulkarnaini, N. A. S., Deli, M. M., Asha'ari, M. J., Jamil, 'Ainul Huda, & Abdullah, S. I. N. W. (2023). Strengthening the University-Maritime Industry Collaborations (UMICs): Technology Issues. *Journal of Applied Engineering and Technological Science (JAETS)*, 5(1), 515–530. <https://doi.org/10.37385/jaets.v5i1.3211>
- Renganayagalu, S. K., Mallam, S. C., & Hernes, M. (2022). Maritime Education and Training in the COVID-19 Era and Beyond. *TransNav*, 16(1). <https://doi.org/10.12716/1001.16.01.06>
- Renganayagalu, S. K., Mallam, S. C., Nazir, S., Ernsten, J., & Haavardtun, P. (2019). Impact of simulation fidelity on student self-efficacy and perceived skill development in maritime training. *TransNav*, 13(3). <https://doi.org/10.12716/1001.13.03.25>
- Reza Emad, G., & Kataria, A. (2022). Challenges of simulation training for future engineering seafarers - A qualitative case study. *Human Factors in Transportation*, 60. <https://doi.org/10.54941/ahfe1002501>
- Romare, C., & Skär, L. (2023). The use of smart glasses in nursing education: A scoping review. *Nurse Education in Practice*, 73(October). <https://doi.org/10.1016/j.nepr.2023.103824>
- Rony, A. H., Kitada, M., Dalaklis, D., Ölçer, A. I., & Ballini, F. (2019). Exploring the new policy framework of environmental performance management for shipping: a pilot study. *WMU Journal of Maritime Affairs*, 18(1). <https://doi.org/10.1007/s13437-019-00165-z>
- Schröder, T. (2019). A regional approach for the development of TVET systems in the light of the 4th industrial revolution: the regional association of vocational and technical education in Asia. *International Journal of Training Research*, 17(sup1). <https://doi.org/10.1080/14480220.2019.1629728>
- Sellberg, C. (2018). From briefing, through scenario, to debriefing: the maritime instructor's work during simulator-based training. *Cognition, Technology and Work*, 20(1). <https://doi.org/10.1007/s10111-017-0446-y>
- Semjonovs, D., Bogdanecs, A., & González, M. J. F. (2015). Instructors' Competence for Enhancing Quality of In-House Training in Maritime Education. *SOCIETY, INTEGRATION, EDUCATION. Proceedings of the International Scientific Conference*, 4. <https://doi.org/10.17770/sie2015vol4.345>
- Sharma, A., & Nazir, S. (2021). Assessing the technology self-efficacy of maritime instructors: An explorative study. *Education Sciences*, 11(7). <https://doi.org/10.3390/educsci11070342>
- Sharma, A., Nazir, S., Wiig, A. C., Sellberg, C., Imset, M., & Mallam, S. (2019). Computer Supported Collaborative Learning as an Intervention for Maritime Education and Training. In *Advances in Intelligent Systems and Computing* (Vol. 785, pp. 3–12). https://doi.org/10.1007/978-3-319-93882-0_1
- Shen, H., Zhang, J., Yang, B., & Jia, B. (2019). Development of an educational virtual reality training system for marine engineers. *Computer Applications in Engineering Education*, 27(3). <https://doi.org/10.1002/cae.22099>
- Sotiroski, L. (2016). The EU and International legal Framework in Maritime Safety. *International Journal of Sciences: Basic and ...*
- Tusher, H. M., Nazir, S., Ghosh, S., & Rusli, R. (2023). Seeking the Best Practices of Assessment in Maritime Simulator Training. *TransNav*, 17(1). <https://doi.org/10.12716/1001.17.01.10>
- UNCTAD. (2024). Global Trade Update (December 2024). <https://unctad.org/publication/global-trade-update-december-2024>
- Urquidi, V. L. (2004). The Role of Sub-regional Agreements in Latin American Economic Integration. In *Latin American Economic Crises* (pp. 115–124). Palgrave Macmillan UK. https://doi.org/10.1057/9781403943859_7
- Vacondio, R., Altomare, C., De Lefte, M., Hu, X., Le Touzé, D., Lind, S., Marongiu, J. C., Marrone, S., Rogers, B. D., & Souto-Iglesias, A. (2021). Grand challenges for Smoothed Particle Hydrodynamics numerical schemes. In *Computational Particle Mechanics* (Vol. 8, Issue 3). <https://doi.org/10.1007/s40571-020-00354-1>
- Velázquez Gomar, J. O. (2014). International targets and environmental policy integration: The 2010 Biodiversity Target and its impact on international policy and national implementation in Latin America and the Caribbean. *Global Environmental Change*, 29. <https://doi.org/10.1016/j.gloenvcha.2014.10.002>
- Vujičić, S., Hasanspahić, N., Gundić, A., & Hrdalo, N. (2020). Assessment for Ensuring Adequately Qualified Instructors in Maritime Education and Training Institutions. *ATHENS JOURNAL OF SCIENCES*, 7(2). <https://doi.org/10.30958/ajs.7-2-4>
- Vuletic, T., Whitfield, R. I., Wang, W., Duffy, A., Gatchell, S., Prins, H., & Leer-Andersen, M. (2017). Improving the creation and management of collaborative networks within the European maritime sector. *Journal of Industrial Information Integration*, 8. <https://doi.org/10.1016/j.jii.2017.05.002>
- Wang, L., Wang, S., & Zhuo, Y. (2015). Marine Practice Teaching based on School-Enterprise Cooperative Education Model. <https://doi.org/10.2991/mcei-15.2015.19>
- Wärtsilä. (2020). Simulation and Training Solutions. <https://www.wartsila.com/docs/default-source/product-files/optimize/simulation-and-training/navigational-simulators-brochure.pdf>
- Youssef, A. M. (2018). Investigating an Interactive Technological Self Study Conceptual Framework for On-board Maritime Education and Training.
- Zaytseva, T. (2016). The introduction of the competence-based approach in educational process of training of skippers. *CEUR Workshop Proceedings*, 1614. <https://doi.org/10.14308/ite000563>
- Zhang, D. (2005). Interactive Multimedia-Based E-Learning: A Study of Effectiveness. *International Journal of Phytoremediation*, 21(1). https://doi.org/10.1207/s15389286ajde1903_3
- Ziarati, R., Demirel, E., & Albayrak, T. (2010). Innovation in Maritime Education and Training. 18th Conference of International Maritime Lecturers' Association, January.