Assessment of Digital Competencies in South African Maritime Education and Training Institutions: A Study of Evaluation Methods for Future Seafarers

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ABSTRACT

The fourth industrial revolution (4IR) and the Covid-19 pandemic have significantly impacted the global maritime industry, requiring maritime education and training (MET) institutions to adapt to new digital competencies. While 4IR created awareness of digital competencies as a key to drive digitalisation, the Covid-19 pandemic 'forced' us to adapt to new situations. The rapid changes in the maritime industry, driven by technological advancements, are resulting in future seafarers requiring digital competencies, and South African MET institutions are faced with delivering seafarer training for students entering this environment.

The study aimed to identify the skills required for seafarers in the digital era and to evaluate the preparedness levels of MET institutions to address this need in courses that offer such skills in the context of South Africa. Best practices in assessing digital competencies in South African MET institutions and identify gaps in current practices were also investigated. The study explored the alignment of identified critical digital competencies with the constructs of the various evaluation methods used to assess these competencies. A qualitative research methodology was employed, using a phenomenological approach to examine the experiences of South African MET professionals regarding digital competency assessment practices. Semi-structured interviews were conducted with seven representatives from MET institutions, encompassing managerial and operational levels.

The findings highlight the need for improved guidelines, industry collaboration and staff development to address skills shortages and to align with global standards. Enhanced frameworks and continuous updates are essential to equip seafarers with the technical proficiency required for the rapidly digitalizing maritime industry, ensuring their readiness to navigate evolving technological and operational landscapes. The study concludes by emphasising the need for standardised competency frameworks, updated curricula, enhanced simulators and international collaborations to align MET institutions to global standards.

Keywords: fourth industrial revolution, frameworks, digitalisation , seafarer training, maritime education

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I INTRODUCTION

Global maritime labour supply and demand are facing challenges because of the rapid evolution of digital technologies and global digitalisation. For this reason, seafarers entering the industry need to be equipped with a certain set of basic digital skills and be integrated with the technological means offered aboard modern ships (Baum-Talmor & Kitada, 2022). Maritime education and training (MET) institutions play a critical role in addressing the shortcomings by predicting and proposing new skills needed to operate these technologies in time and implementing the training of these skills into the development of a new educational model. In South Africa, as in most developing countries globally, future seafarers face a large number of obstacles in obtaining access to the facilities, which directly forces them to enhance the required digital competencies (Dyers, 2020). Consequently, what arises is the question of how to approach the employment of suitable assessment instruments for seafarers' digital skills in South African MET institutions.

Therefore, the primary objective of this article is to identify the assessment methods for seafarers' digital competencies in South Africa. Besides answering this question, we strive to answer the following research questions (RQ):

RQ1: What are the recognised and used frameworks, methods and evaluation tools geared towards seafarers' competencies in the area of emerging technologies on the global educational level?

RQ2: What approaches to teaching and evaluating digital information are presently being applied in South African maritime operational education?

The precise examination of these questions could assist in compiling an instrument for alleviating the present assessment of the ability to operate digital equipment, hardware, software and digital information in South African emerging seafarers.

South Africa boasts a variety of MET institutions that oversee seafarer training and the maritime industry will remain relevant to the economy if MET institutions successfully train and provide professionals with the appropriate skills to be competitive. The study investigates how advances in technology are bringing about profound qualitative changes and transformative impacts on seafaring, and how MET institutions are adapting to that change. A better understanding of the preparedness of MET institutions can support effective decision-making and strategic resource allocation towards a skill set that matches the requirements of a more digital maritime environment. The results from this study will enhance the existing body of literature regarding maritime education and training, specifically concerning the digital revolution taking place within the sector.

II LITERATURE REVIEW

Seafarers play a crucial role in the operational crew and a standardised definition of their competencies is necessary for efficient operation. The International Maritime Organization (IMO) sets the International Convention on Standards of Training, Certification, and Watchkeeping for Seafarers (STCW), which guides MET institutions worldwide to adhere to IMO requirements, particularly for seafarer training. The STCW Code requires institutions to continually enhance skills in teaching to adapt to ever-changing industry trends (Mohammed, 2019). However, several gaps in STCW Convention and Code were identified, including digitalisation and emerging technologies (IMO, 2024). A comprehensive review of the STCW Convention and Code highlights the need of revise current standards to include simulator-based training, virtual reality (VR) and augmented reality (AR) technologies, enabling more effective and flexible learning opportunities for seafarers (IMO, 2024).

The South African maritime industry is experiencing rapid technological development, leading to more formal responsibilities that require decision-makers to possess digital skills. However, the current workforce is technologically challenged and experiencing skill gaps. There is a growing demand for seafarers who can navigate the increasingly complex digital environment. An effective policy approach should ensure training programmes are available to upgrade the necessary digital skills, potentially increasing the skills of a pool of labour that currently specialises in unskilled and unprotected work (Maghoromi, 2023). Investing in foreign-going seafarers can help create jobs, ensure inclusivity across social lines, generate high-grade revenue for poverty alleviation and ensure sufficient goods are brought into the country's ports.

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Overview of the South African maritime sector

South Africa occupies a strategically significant position along one of the world's busiest and most competitive shipping routes, with a coastline spanning over 3 000 kilometres (Meyiwa & Chasomeris, 2020). The country boasts the 34th largest economy globally and the second largest in Africa, with key maritime hubs such as Durban, Richard's Bay, East London, Gqeberha, Ngqura, Mossel Bay, Saldanha Bay and Cape Town playing pivotal roles in regional and international trade. The maritime economy is diverse, encompassing sectors such as offshore oil and gas exploration, maritime tourism, marine technology and sustainable environmental practices.

Figure 1: Overview of the South African maritime sector
Source: Author's own work.

Given the rapid technological advances in the maritime industry, there is an increasing need for MET institutions to equip seafarers with the skills required to operate next-generation ships and advanced systems. Figure 1 gives an overview of South African maritime sector, while this study examines how technological progress is driving significant qualitative and transformative changes in seafaring and how MET institutions are adapting to address these shifts. Ensuring that the workforce is equipped with the competencies to meet the demands of these advances is critical for maintaining the industry's relevance and aligning with the evolving skills supply-demand dynamics (Grimmet, 2023).

Digital competencies in the maritime industry

The introduction of digital technologies in the maritime industry necessitates the acquisition of various digital skills for working in a workplace. These skills include the ability to use digital technologies, communications tools and networks to access, manage, integrate, evaluate, create and communicate information (Lušić et al., 2019) Seafarers must demonstrate these digital skills, which are classified into four groups, namely entry-level skills, basic skills, intermediate level skills and advanced level skills (Sharma, 2023).

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The maritime industry is, by all assessments, one of the most globally interconnected industries as a result of its extensive digital value chain. Although the introduction of digital technologies has the potential to transform the maritime industry broadly, there is a need to embrace digital competencies throughout the MET system. It is fundamental for MET systems to produce future seafarers who are digitally literate and competent for their workplace.

Digital transformation in the maritime industry involves the application of cutting-edge digital technologies to support business enhancements, such as increasing customer experience and streamlining procedures (Morakanyane, Grace & O'Reilly, 2017). However, there has been a lack of education for seafarers to help them cope with such a big change in technology on board ship. Inadequate training has resulted in marine casualties with significant human, financial and ecological consequences.

In the near future, the growing use of artificial intelligence (AI) systems is expected to change the way navigational data are handled on board and ashore. To ensure safe interactions between vessels with different autonomy levels, AI-based system components that will process large datasets to provide the operator with only useful information are needed. Maritime human operators will be required to interact with a wide variety of AI tools daily (Oksavik, Hildre & Pan, 2021). Therefore, developing a set of digital competencies in future seafarers is essential.

Furthermore, future seafarers involved in navigation are required to have the basic digital competencies to navigate using electronic chart display and information systems and global navigation satellite system integration, and run the ship's business using word processing and email communications (Oksavik, Hildre & Pan, 2021; Demirel, 2020). With the maritime industry moving persistently towards a digital world, more and more of its operations have come to rely on interconnected information technology (IT) systems. This opens the door to potential cyber threats. The possibility of a cyberattack is significant and, in some cases, could potentially cause the loss of a vessel and even a loss of life. There is, therefore, a real need for reliable cyber-resistant solutions and training for the crew in case of a cyber incident (Mraković & Vojinović, 2019). Many organisations are implementing electronic navigational charts and other communication tools to improve the efficiency of the maritime transport industry. However, due to the openness of digital systems, many challenges have to be considered regarding the security of digital systems. The increasing reliance on digital systems has raised concerns over the risk of cyber incidents in the shipping industry. Such risks could possibly endanger the safety of life, the vessel itself, and the overall maritime system and trade at large.

Seafarers entering new fields and taken on as crew are required to have a digital communications capabilities to safely transfer data between the shore and the ship that are consistent with conventions and standards (Ceylani, Kolçak & Solmaz, 2022). As maritime safety relates to operations at sea and the prevention of pollution, the continuing use of operational technology principles underpins these activities. The situation has gradually started to change, with digital technology platforms such as maritime simulation that look at the operation of the ship as a multifaceted machine. These developments are particularly relevant to the undergraduate education and training of navigators (Sharma, 2023).

There has been a direction for the development of seafarers to include the ability to use and adapt to new technologies as a means of ensuring safe, secure and efficient maritime activities (Demirel, 2020. The vision of the future of MET highlights the fact that the advantages of digital technologies will unlock potential in the development of MET practices and, thus, delivering relevant, supportive information is necessary. Progressive national and global states will benefit through present and future.

A study by the International Transportation Worker's Federation and World Maritime University suggests that, by 2040, the demand for seafarers may decline because of the advent of highly automated ships. The study states that workers with routine duties and low/medium skill levels may lose their jobs as a result and, therefore, the marine sector will have to update

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its regulations for seafarers and retrain its workers to adjust to these developments. Furthermore, the study mentions that it might be necessary to amend the STCW, which specifies basic competency criteria, to account for emerging positions like shore/remote control centre operators and autonomous marine operations because, in contemporary sociotechnical systems, non-technical skills, that is, cognitive, social and personal resources, are also becoming more and more significant (Sharma, 2023).

The development of MET instructors, shown in Figure 2, is essential for ensuring that maritime students are well prepared for the technological challenges they will face. By equipping instructors with the characteristics, professional development opportunities and performance skills outlined in the figure, MET institutions could foster a learning environment that aligns to global standards and the needs of the maritime industry.

In addition to filling current gaps, this framework sets a foundation for continuous advancement in maritime education, ensuring that both instructors and students are adequately prepared for the future.

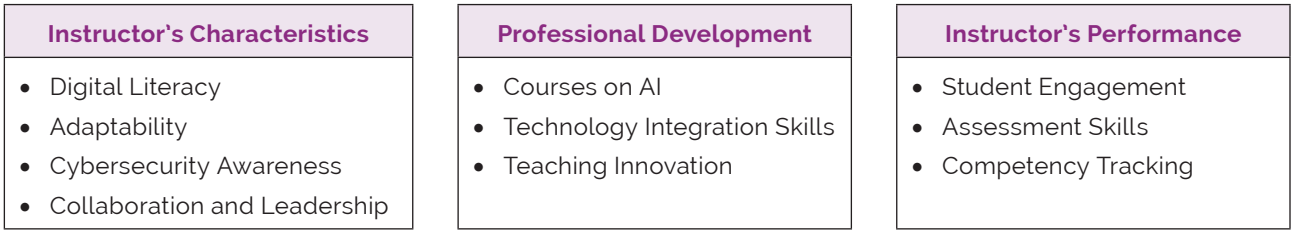

Figure 2: Possible further components for an effective MET instructor in the digital era
Source: Author's own work.

Developing seafarers competencies in emerging technologies

MET institutions have evolved as a result of the fourth industrial revolution, with seafarers now employed in various sectors such as shipyards, ports, marinas, shipping and logistics firms (Demirel, 2020). This study evaluates the preparedness of MET institutions to undertake future developments in identifying seafarers' skills in the digital era. Seafarers' roles are evolving, emphasising the human aspect. As maritime shipping is a globalised industry, seafarers' skills and competencies must be harmonised according to global standards. Flag states have the responsibility to ensure compliance with the STCW Convention (Manuel & Baumler, 2020).

The global maritime industry is increasingly reliant on technology at sea and ashore and the industry has a need for personnel who are adequately trained to work with new technologies (Aiello, Giallanza & Mascarella, 2020). New technological advances bring change to operations, working methods, environment and new needs for safety considerations and risk management, and the change in competency needs for new technologies brings fresh challenges to training and education (Sanchez-Gonzalez et al., 2019). There is a worldwide collaborative effort to develop regulations, standards and guidance on how to address the competencies of seafarers in new technologies. Consideration should be given to how frameworks, methods and evaluation tools can be used and implemented effectively in the context of different educational systems and training infrastructures, and how their applicability and effectiveness can be validated.

Digital skills are also recognised at the IMO level. The STCW training framework requires modernisation to adapt to the ongoing technological development. Several specific areas identified for comprehensive review of STCW are related to digitalisation (Nhleko, 2023) different MET systems are used to not only produce

https://doi.org/10.47348/SAJMET/2024/i1a8

eligible maritime professionals but to ensure that they comply with the requirements of the International Convention on the Standards of Training, Certification and Watchkeeping (STCW). The lack of specific training requirements in the STCW framework for managing cyber threats is noted as a significant gap and, to bridge the gap, the inclusion of new knowledge–usage–proficiency requirements was advocated in order to address this growing challenge. These additions are expected to equip seafarers with the skills needed to safeguard operational systems against cyberattacks, ensuring both safety and economic resilience (IMO, 2024).

There are various competency frameworks in use across the MET landscape and some of these focus on the technical competencies that seafarers need to do their jobs, while others embrace a broader perspective, incorporating soft skills that are now considered essential for seafarers (Sharma, 2023). The most widely known competency frameworks are those from IMO, which set standard training requirements for seafarers in terms of both their knowledge and skills, and the training environments in which these must be taught. Competency frameworks have been in existence in the maritime domain since the mid-1990s (Baumler, Bhatia & Kitada, 2021). It considers what motivates seafarers to hide their violations through record adjustment. The research adopted a qualitative research methodology to understand this industry problem, involving the use of semi-structured interviews. These were conducted with 20 seafarers to analyze their recording practices and adjustment of records. The participants underline that the imbalance between workload and manning levels leads to recurrent violations, particularly during port-related operations and for seafarers on the 6 On/6 Off watch system. To hide their violation and feign compliance, the data revealed that almost all seafarers in our study adjusted work and rest hours' records. The fear of the consequences of non-conformities during third party inspections is the main driver for such adjustment of records. Employment concerns and job insecurity tend to make seafarers submissive to the companies' interests, and they place the ship interests first. Flag State, Port State, and shipping companies seem to disregard violations and adjustments. Therefore, adjusting records seems a low-risk option for seafarers. However, systematic adjustment of records points to failures of the International Safety Management (ISM). During this time, the maritime industry has experienced significant change as a result of technological advancement and the associated redefinition of job roles and task requirements. These changes (and real-world events like marine accidents) have necessitated updating existing competency frameworks and the development of new ones. The changes also reflect the tensions between global best practice and local interpretation/adaptation (Nhleko, 2022). There is still a gap in the extant literature in relation to sustainable development and maritime education. This indicates that the SD concept and its implications for MET have not been addressed adequately. The aim of this research work was to analyse the relationship between sustainable development curricula and MET in a South African institution. This included developing a model for assessing the integration of SD in Maritime Higher Education (MHEI).

The take-away from this discussion is that educational institutions need to collaborate with industry leaders to properly support the application of frameworks. By providing an overview of the real-world applications of frameworks, this section helps the reader understand the operational importance of competency frameworks. Ultimately, the aim is also to help narrow the gap between theory and practice in seafarer training.

Training evaluation

Training evaluation is a methodical process that assesses the effectiveness of a training programme, involving various actors, such as clients, trainers and trainees. It involves formulating questions, gathering relevant data, disseminating information and assisting in decision-making. Evaluation ensures training goals are met and on-the-job performance significantly improves (Benziane & Houcine, 2021). There are two components to training evaluation, namely formative and summative. Formative evaluation assesses how effectively a training programme is organised, the extent to which participants gain knowledge and their overall satisfaction with the experience. This type of evaluation provides valuable feedback that is used to refine and enhance the programme's effectiveness by identifying areas for improvement (Ritzmann,

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Hagemann & Kluge, 2014). In contrast, summative evaluation focuses on measuring the outcomes of a completed programme, particularly its impact on trainees' behaviour and overall performance (Ritzmann, Hagemann & Kluge, 2014). Both trainers and trainees play a critical role in achieving the desired results of training programmes, and their evaluations are instrumental in further improving a programme's design and implementation. Kirkpatrick's model is widely accepted and used in various fields. Evaluation considers content, transference of information and perceived efficacy. It plays a critical role in creating curricula and programs in education, often using commercial models to evaluate learning objectives. Evaluation helps organisations make decisions on programme proposals, development and formative and summative assessments. It also helps identify areas for improvement and facilitates a cycle of continual improvement. The importance of training evaluation lies in measuring the effectiveness of knowledge and skills acquired during training in practical situations, establishing a connection between training and job performance, and identifying areas for enhancement.

Training evaluation models play a crucial role in assessing the effectiveness, quality, efficiency and changes in trainee competencies. Five models are discussed in this study and the strengths and limitations of each model are presented in Table 1, emphasising the importance of understanding and applying these models in the context of MET institutions:

1. **CIRO model**: Established in 1970, the model comprises four elements, namely context, input, reaction and results (CIRO). Context evaluation assesses a company's environment and culture, while input evaluation focuses on the implementation and efficacy of training activities. Reaction evaluation collects data on the efficacy of a training session, while outcome assessment evaluates the immediate, intermediate, and long-term impacts of an undertaking (Ali, Tufail & Qazi, 2022).
2. **Kauffman model**: Introduced in 1994 by Roger Kaufman and John M. Keller as a learning assessment approach, the Kauffman model has five levels: Level 1A represents the input; Level 1B represents the process; Level 2 represents the acquisition; Level 3 represents the application; Level 4 represents the organisational payoffs' and Level 5 represents the societal outcomes. The model emphasises the augmentation of societal value and the ongoing improvement of processes (Ali, Tufail & Qazi, 2022).
3. **Phillips return on investment (ROI) model**: This model adds a new level called 'ROI' to broaden the range of Level 1 and incorporates students' plans to use their training skills in professional settings. This level provides useful data and empirical information that supports the recovery of expenses associated with training initiatives (Ambu-Saidi et al., 2024).
4. **Kirkpatrick model**: Developed by Donald Kirkpatrick, the model is a popular paradigm for assessing in-company training. It emphasises outcomes and serves as an inspiration for the other models, including the CIPP model (Alsalamah & Callinan, 2021).
5. **CIPP model**: Created in 1971, this model focuses on decision-making and involves four interconnected elements, namely context evaluation, input evaluation, process evaluation, and product evaluation (Alhaji, Yew & Razak, 2020).

https://doi.org/10.47348/SAJMET/2024/i1a8

Table 1: Training evaluation models, their strengths and limitations

Training Evaluation Models	Strengths	Limitations
CIRO	Includes evaluation of the surrounding circumstances and analysis of the provided information.	Does not necessitate evaluation of results.
	Sequential phases for comprehensive assessment.	Demands cooperation from all parties involved.
KAUFMANN	Includes evaluation of societal impacts and appraisal of value.	Extensive data collection is necessary to determine the return on investment (ROI).
	Enhances Level 1 by incorporating the aspects of enabling and reacting.	Theoretical underpinnings can constrain practical application.
	Addresses both the internal and outward repercussions.	Not appropriate for every training scenario.
PHILLIPS ROI	Emphasises the importance of economic value and return on investment (ROI). Demonstrates the economic advantages of training.	Calculating ROI with precision might be difficult due to the presence of subjectivity while trying to differentiate net benefits.
KIRKPATRICK	The evaluation process is guided by a hierarchical framework.	Assumes cause and effect connections between different levels.
	This approach emphasizes the assessment of participant responses, educational achievements, modifications in behaviour and the impact on the organisation.	Lack of comprehensive accounting for both individual and contextual elements.
	Highlights the significance of the effect on organisational objectives.	Inadequate instructions for dealing with contextual issues.
	Universally embraced and acknowledged in the field of training.	The application can differ depending on the setting and objectives.

https://doi.org/10.47348/SAJMET/2024/i1a8

Training Evaluation Models	Strengths	Limitations
CIPP	The CIPP model is highly versatile and may be easily applied to various evaluation circumstances due to its lack of specific application or solution-oriented design.	One could argue that the strategy blurs the boundary between evaluation and other investigative procedures, such as needs assessment.
	The comprehensive approach of a program can be used to evaluate its design, programme outcomes, and adherence to core principles.	In the realm of performance enhancement, this paradigm is not as widely recognised or employed as other models.

Source: Adapted from Ambu-Saidi et al., 2024 and Ali, Tufail & Qazi, 2022.

This study uses the CIPP Model to assess the preparedness of MET institutions in South Africa for the digital maritime era. The model is applicable across various evaluation scenarios and could help identify skill needs related to digital ship, digital shipping, maritime digitalisation and new maritime professions (see Figure 3). The CIPP model helps align programme objectives, target conditions, curriculum and organisational capabilities to the evaluation process, considering the surrounding environment. By addressing the social challenge of developing a hybrid workforce, stakeholders can develop a shared understanding of digitalisation challenges and address skill needs on a common level.

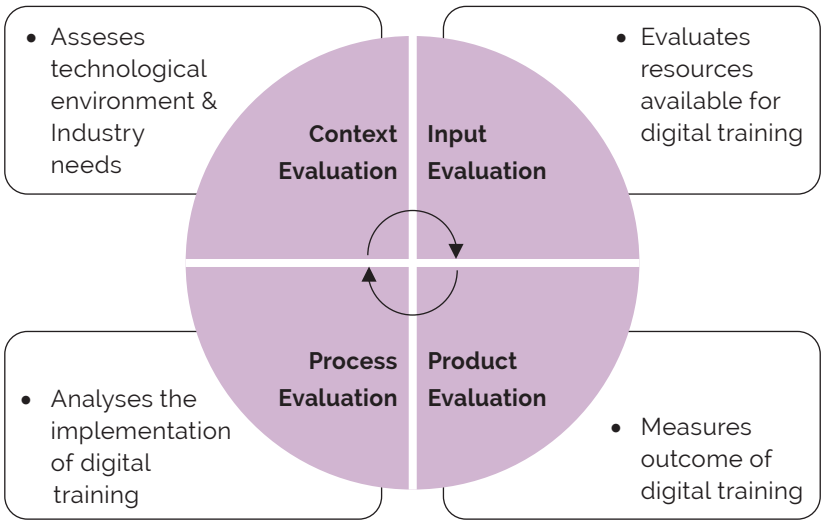

Figure 3: CIPP model
Source: Adapted from Kuo et al., 2012.

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III RESEARCH METHODOLOGY

This section offers a comprehensive explanation of the research procedures employed by the researcher, including a comprehensive analysis of the research design, a brief examination of the limitations of the technique employed and a final summary.

South Africa presents an interesting case for the study as it has a unique coastline made up of a number of sea ports. The international maritime sector is currently undergoing extensive digitalisation and technological innovation, which is rapidly changing the overall nature of maritime work and operations (Demirel, 2020). South African seafarers face many challenges and opportunities within the context of South Africa's maritime sector and there is a need to build a pool of quality maritime personnel in line with national, regional and international human resource development strategies.

The qualitative research method was chosen for this study because the research questions sought solutions cannot be answered by subjecting data to statistical procedures (Baskarada, 2014)the qualitative case study method is not well understood. Due to conflicting epistemological presuppositions and the complexity inherent in qualitative case-based studies, scientific rigor can be difficult to demonstrate, and any resulting findings can be difficult to justify. For that reason, this article discusses methodological problems associated with qualitative case-based research and offers guidelines for overcoming them. Due to its nearly universal acceptance, Yin's six-stage case study process is adopted and elaborated on. Moreover, additional principles from the wider methodological literature are integrated and explained. Finally, some modifications to the dependencies between the six case study stages are suggested. It is expected that following the guidelines presented in this article may facilitate the collection of the most relevant data in the most efficient and effective manner, simplify the subsequent analysis, as well as enhance the validity of the resulting findings. The article should be of interest to students (honour, masters, doctoral. The phenomenological approach was chosen for this study as it examines people's experiences with a phenomenon based on participant descriptions.

The study aims to identify gaps and opportunities for improvement in MET institutions' assessment practices in South Africa. This study aimed to assess the digital competency of seafarers in South Africa by means of qualitative research, sample selection and data collection methods. The target population consisted of lecturers and senior staff from MET institutions in South Africa familiar with the process. Sampling was used to select a small number of participants who had experienced the central phenomenon.

The data collection process involved establishing contact with respondents, requesting interviews, and providing consent forms. Semi-structured interviews were conducted with seven representative individuals involved in the MET system in South Africa, including personnel from different training institutions at the managerial and operational levels.

Data analysis

The data collected from semi-structured interviews was analysed using thematic analysis, a qualitative method that focuses on identifying, analysing and reporting themes in the data. Thematic analysis, as defined by Braun and Clarke (2006), involves systematically coding data to uncover patterns and themes that directly relate to the research objectives. For this study, interview recordings were first transcribed verbatim, with transcripts carefully reviewed against recordings to ensure accuracy.

The analysis followed a structured process. First, the researcher thoroughly reviewed the transcripts multiple times to gain familiarity with the content. Next, initial codes were generated using the comment function in Microsoft Word. The codes were then organised into potential themes using an Excel spreadsheet. These themes were mapped to align to the research questions, ensuring that the analysis remained focused on the study's objectives. Themes were identified at a semantic level, where the focus was on the explicit meanings of participants' responses, rather than interpreting underlying or implicit meanings (Braun & Clarke, 2006). This thematic organisation provided a narrative framework for analysing and responding to the research questions.

https://doi.org/10.47348/SAJMET/2024/i1a8

Table 2: The CIPP model for the data analysis

CIPP Component	Description
Context Evaluation	The analysis focused on understanding participants' perspectives in relation to the research questions. Thematic analyis, as recommended by Braun and Clarke (2006), was selected to uncover explicit patterns and themes in the qualitative data. This ensured the findings were meaningful and aligned with the study's objectives.
Input Evaluation	The input consisted of qualitative data gathered through semi-structured interviews. Interview recordings were transcribed verbatim and reviewed for accuracy. Microsoft Word's comment feature and Excel spreadsheets were used to systematically code and organize data in themes. Thematic analysis was chosen for its ability to provide structured and detailed insights into qualitative data.
Process Evaluation	The analysis followed a step-by-step approach: (1) transcripts were reviewed multiple times for familiarization; (2) initial codes were generated from key sections of text; (3) these codes were transferred to Excel and grouped into potential themes. A semantic approach was used, focusing on explicit meanings directly stated by participants, without interpreting deeper implications.
Product Evaluation	The outcome was a set of clear and organized themes that addressed the study's research questions. These themes provided valuable insights into participants' perspectives, ensuring the analysis was reliable, relevant, and aligned with the study's objectives.

Source: Author's own work.

IV FINDINGS

The findings are organised into four core themes identified during the analysis of the semi-structured interviews. The first theme examines how South African MET institutions assess capabilities, with particular attention to digital competency evaluation. The second theme explores the frameworks and guidelines MET institutions use or reference within the context of capability assessment. The third theme addresses concerns related to the adequacy and effectiveness of current practices in competency mapping and career pathing. Finally, the fourth theme reflects on MET institutions' perceptions of the current challenges and the opportunities for growth and improvement in the assessment of digital competencies.

Participant summary

The study involved seven participants, four lecturers, two training instructors and one managing director from a training institution (Table 3). These individuals provided diverse perspectives and valuable insights into the practices, challenges and opportunities surrounding the assessment of digital competencies in South African MET institutions. Their professional roles ensured a well-rounded understanding of both operational and strategic aspects of digital competency evaluation within the maritime industry.

https://doi.org/10.47348/SAJMET/2024/i1a8

Table 3: Participant summary

Participant Number	Role	Gender	YRS of experience (current role)
1	Training Instructor	Male	7 yrs
2	Lecturer	Male	5 yrs
3	Senior Manager	Male	12 yrs
4	Lecturer	Male	3 yrs
5	Instructor	Male	5 yrs
6	Lecturer	Female	20 yrs
7	Lecturer	Male	3 yrs

Analysis

The findings of this study are based on the CIPP model and provide a detailed analysis of how South African MET institutions address the assessment of seafarers' digital competencies. These findings were extracted from interviews with academics and industry representatives and are summarised with participants quotes to underscore the perspectives shared during the study (Table 4).

Table 4: CIPP model for the findings

CIPP component	Findings	Supporting quotes	Implications
Context	Lack of standardised assessment practices. Reliance on individual instructors' preferences.	P7: 'There is nothing to show that competency now'. P4: 'No specific frameworks'.	Lack of uniformity affects the reliability and consistency of assessing students' digital competencies.
Input	Importance of digital skills in maritime operations and safety.	P6: 'Challenge, of course, is the level of computer literacy of our incoming students'.	Institutions need to address varying skill levels of students from disadvantaged backgrounds.
	Dependence on STCW and South African Maritime Safety Authority (SAMSA) guidelines. Bureaucratic delays limit flexibility.	P3: 'Your knowledge, skills, and proficiency are all detailed quite clearly in the STCW guidelines'. P7: 'The integration with the institution is challenging due to bureaucracy'.	While international guidelines are valuable, a lack of local adaptability hinders progress in integrating new technologies and practices.

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CIPP component	Findings	Supporting quotes	Implications
	High costs of simulators and infrastructure upgrades.	P3: 'The procurement of such training equipment is incredibly expensive'. P2: 'The institution didn't have money for this. It cost millions.'	Funding challenges delay advancements, preventing students from accessing state-of-the-art equipment and resources.
Process	Challenges in implementing digital competency training, including financial, infrastructural and skill-related barriers.	P5: 'Computer literacy especially for the old seafarers … . There was not a lot of technology then.'	Resource constraints and varying literacy levels create unequal opportunities for learners.
	Shortage of qualified instructors.	P4: 'You cannot teach students on equipment that you've never used before'.	Addressing instructor qualifications is critical to ensuring effective delivery of digital competency training.
Product	Opportunities for international collaborations and advanced simulators.	P2: 'We foster international collaborations through something called [collaborative online international learning] COIL'. P4: 'Controlled training environments using simulators can address shortages of ships'.	Stronger partnerships and new technologies can transform maritime training practices, aligning them with global standards.
	Curriculum updates to include more practical digital training.	P5: 'The industry is moving towards Class A simulators, which are as realistic as possible'.	Updating curricula with cutting-edge simulation technology enhances practical learning experiences.

The study revealed that there is no standard practice for assessing digital competencies in MET institutes. Different types of assessment methods are used, with some relying on simulations and online learning assessments. The integration of technology has progressed to the extent of assessing students electronically, with simulators and online learning assessments being used. The study also revealed a mandatory electronic learner management system in the form of a blackboard.

The study highlights the importance of integrating technology into assessing digital competencies in the maritime industry, with the use of simulators as one method of assessing digital competencies by creating multiple training scenarios. The study identified two guidelines for MET institutions in South Africa, namely the STCW Convention and the national regulations set by the SAMSA. The STCW Convention applies to all seafarers on board international voyages, while SAMSA is responsible for the publication of the Training Standards Code. The SAMSA standard of training and assessment is adopted from the STCW Convention, which sets minimum qualification requirements for seafarers at different career progression levels. However, the minimum requirements have been challenging to comply with and bureaucratic challenges have hindered the integration of new technologies.

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There is currently no standardised framework for assessing digital competencies, leading to inconsistent assessment quality and reliability. Additionally, there are no specific frameworks in field navigation and marine engineering. The study also identified gaps in MET institutions in respect of assessment of digital competencies. High costs of acquiring top-of-the-line training equipment such as simulators and the need for infrastructure building are significant challenges. Additionally, incoming students often lack basic computer literacy skills because they come from poor and disadvantaged backgrounds, which can affect competency validation. The study highlights the need for improved guidelines, standardised frameworks and improved training institutions to better prepare students for the real world of maritime.

The increasing reliance on computers, IT and automated processes on board ships has created an urgent need for computer-literate seafarers. Seafarers in older generations might struggle with digitalisation and the adoption of new technologies, which are crucial for the safe and efficient operation of ships. The lack of technical experts in maritime education and training institutions is due to the requirements and qualifications required by the maritime authority of South Africa. This gap in skills will delay the progress of students and affect the supply of skilled seafarers.

To align with best practices, the maritime education and training sector should further establish strong partnerships with industry. Participants expressed their views on partnerships, such as fostering international collaborations using the COIL approach and finding credible training centres in foreign countries. They also suggested that a controlled training environment using simulators could address the shortage of ships.

The use of technology in maritime education has become a necessity but it brings both advantages and challenges. The education and training of seafarers should consider the technical advances within international conventions. The findings of this research are significant because they provide evidence that MET institutes in South Africa have an overall low level of preparedness in identifying the needs of seafarers in the digital era. Opportunities for improvement exist through continuous updates, industry collaboration and staff development.

The findings from the interviews highlight critical gaps in the assessment of digital competencies, the integration of advanced technologies and the support provided to facilitators in South African MET institutions. While challenges such as limited funding, rapid technological advancements and the evolving needs of the industry persist, opportunities for improvement are evident. These opportunities include the continuous updating of assessment practices, fostering collaboration with industry stakeholders and prioritising staff development to address skills shortages and align with global standards.

A key issue is the limited use of interactive and disposition-based assessment methods that could better evaluate the readiness of seafarers to meet the demands of digitalisation. Current approaches focus on imparting factual knowledge, which only provides a foundational understanding of digital competencies. This approach neglects the more nuanced and dynamic aspects of the digital shift, such as how seafarers adapt to changing working conditions and technological environments. Consequently, MET institutions are not adequately equipping seafarers to navigate the broader implications of digitalisation on their roles.

Furthermore, resources are disproportionately directed toward basic-level training rather than leveraging adaptable frameworks and ongoing professional and policy dialogues. Such frameworks would enable institutions to anticipate and respond to the complex, evolving challenges posed by digitalisation. Addressing these gaps by way of strategic planning, industry collaboration and the adoption of comprehensive, interactive assessment methods would ensure that MET institutions remain relevant and effective in preparing seafarers for the demands of a rapidly digitalising maritime industry.

Seen through the lens of the CIPP model, this study highlights the fragmented nature of digital competency assessment practices in South African MET institutions. While global frameworks such as STCW and SAMSA

https://doi.org/10.47348/SAJMET/2024/i1a8

provide overarching guidelines, inconsistencies in implementation, financial barriers and a lack of qualified facilitators hinder progress. However, the study also underscores opportunities for improvement, particularly with international collaboration, technological integration and standardised assessment frameworks. Strategic reforms in these areas would enable MET institutions to better prepare seafarers for the demands of an increasingly digital maritime industry.

V DISCUSSION

The rapid advancement of digital technologies has led to increased efficiency and safety at sea but there is a disconnect between the actual requirements on board ships and the current degree of integration in South Africa. The absence of standards could result in varying evaluations of skills in the maritime field. The study highlights the need for more standardised frameworks and assessment tools to accurately measure a seafarer's ability to operate sophisticated digital systems. Simulators and online learning platforms are perceived as useful tools for enhancing training effectiveness. However, the institutions are bound by the STCW Convention criteria, but there are shortcomings in implementing these standards because of bureaucracy.

Continuous evaluation and adaptation of training programmes, including both the technology and the pedagogical approaches, are essential to ongoing success. While this might be evident to many, it is frequently overlooked in practice, particularly when funding and personnel change at training institutions. Stakeholder engagement and collaboration are crucial to success, particularly at the early stages of framework implementation. These processes take time and can be hindered by misunderstandings, differing priorities, and cultural differences. They also need to be more systematic and planned rather than dependent on personal agency. Although recommended as best practice, several challenges make it difficult to fully implement this approach. It can be time-consuming when changes in personnel occur and it can be challenging to find middle ground when industrial players and educators have different priorities and perspectives (Vujičić et al., 2022). The study also highlights the gaps in current practices in South African MET institutions regarding digital competencies, such as high costs for procurement and maintenance of training equipment and the lack of fundamental computer literacy in students from underprivileged backgrounds.

Opportunities for improvement include improving the use of simulators in training, fostering industry relationships and addressing the digital gap. The findings contribute to existing knowledge on the preparedness of MET institutes globally and the need to develop strategies to improve preparedness, especially in understanding big data and learning analytics technologies.

VI CONCLUSION AND RECOMMENDATIONS

The maritime industry is a global leader and it is crucial for countries like South Africa to train competent seafarers. This study examined the readiness of MET institutions to identify seafarers' needs in the digital era. It found that there are still limited actions being taken to address these needs. The research highlights the non-standardised quality of digital competency assessment in MET institutions, with disparate methods used to measure vessel competences.

The findings of the study also emphasises the need for MET institutions to align their practices to international guidelines and national frameworks. However, bureaucratic barriers and a lack of detailed action plans hinder the implementation of digital competences. The study also highlights weaknesses in current practices, such as high procurement costs for modern training equipment and a lack of capable trainers. These issues prevent MET institutions from adequately training students on the digital skills required in today's maritime industry.

The study findings suggest that MET institutions can improve their digital competency assessments by combining best practices with international collaborations and improved simulators. This could lead to updates in curricula, training methods, and aligning with global standards.

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The study aligns to three United Nations Sustainable Development Goals, namely Quality Education; Investment in Scientific Research and Innovation; and Partnership for Educational and Skills Development. By ensuring seafarers acquire necessary knowledge, skills, attitudes and values in the digital arena, the goal will contribute to more sustainable development.

This case study on the preparedness of maritime education and training institutions in South Africa highlights the need for MET institutions to identify the changing needs of seafarers in response to the rapid dependence of the industry on digital technology. This will help keep training programmes current and relevant in the digital age. Additionally, there is a need to develop an economic rationale for investing resources in keeping training up-to-date with identified digital seafarer needs. The study is limited to the perspectives of participants from two higher education institutions and three technical schools focusing on MET in South Africa and did not consider the opinions of other stakeholders such as maritime regulators and shipping companies.

Recommendations for MET institutions include a standardised competency framework, updating guidelines, secure investment in infrastructure and resources, boosting computer literacy and focusing on instructor training and recruitment. These recommendations contribute to practical policy considerations and implications for MET institutions in identifying seafarers' needs and addressing the needs of the maritime industry and its occupational groups.

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