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A study on digital literacy and influencing factors among Chinese seafarers

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Digital literacy and skills have become critical indicators of international competitiveness, gaining attention across all sectors. As digital transformation accelerates, the shipping industry, a pivotal center of global trade, faces new challenges. The advent of Maritime Autonomous Surface Ships (MASS) further heightens the demand for enhanced digital literacy among seafarers. This study, guided by UNESCO's Digital Literacy Global Framework (DLGF) and incorporating specific digital skill requirements for seafarers alongside the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) regulations, developed a tailored survey to assess the digital literacy of Chinese seafarers. Using an online survey, responses from 321 seafarers were collected, with participants selected based on professional experience across various maritime positions. The study examines the impact of factors such as education level, maritime experience, job position, and IT training on digital literacy levels. Results indicate that, overall, seafarers' digital literacy is moderate, though those who participated in IT training show enhanced competencies. However, the study's focus on Chinese seafarers may limit the generalizability of the findings to the broader, multinational seafaring population. Further research with more diverse samples is necessary to improve the applicability of the results to global seafaring contexts.

Keywords Seafarers, Digital literacy, Digital competences, Maritime Autonomous Surface Ships (MASS), Maritime Education and Training (MET)

Improving citizens' digital literacy and skills occupies a crucial position in major strategic decisions of the international community. The United Nations (UN) released the Roadmap for Digital Cooperation[1] in June 2020, with eight key action areas that are relevant to digital literacy and skills. The European Union (EU) released the Digital Competence Framework for Citizens (DigComp 2.2) in March 2022[2], with new examples of the three components of digital literacy: knowledge, skills, and attitudes, in order to better support the implementation of the European plan of Digital Compass (2030 Digital Compass: the European way for the Digital Decade). Similarly, the United States and Singapore have launched national plans for digital literacy education[3,4]. The United Kingdom and Australia have both adopted the improvement of citizens' digital literacy and skills into their digital strategies[5,6]. China has also introduced a series of special policies on improving digital literacy and skills for all[7,8], focusing on its improvement for different groups.

The shipping industry plays a crucial role in the global economy, facilitating over 80% of international trade in goods[9]. With the development of technologies, especially in the field of digitalization and automation, the industry is undergoing an impressive digital transformation. This transformation is expected to lower operating costs, improve efficiency, and extend equipment life. However, it also brings about a significant impact on the human resource structure of the shipping industry, particularly on the career and skill requirements of seafarers[10]. Specifically, with the development and application of MASS, there will be less reliance on traditional maritime skills and an increased need for advanced technical skills. As a result, the traditional role of the seafarer may face significant changes. On one hand, automation may reduce the demand for traditional seafarers[11], especially in unskilled positions while requiring seafarers to equip themselves with more advanced digital skills and technical knowledge so as to fit with the operational requirements of new types of ships, for example, big data analytics, application of ICT (Information and Communication Technology) and management and maintenance of automated systems[12]. On the other hand, the newcoming technologies may create new positions and professional paths[13–16], for example, if the ship realizes totally unmanned operation, then the operators of

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Shore Control Center Operator (SCCO) will have to be with higher level of skills[16] to meet the new requirements of automated and digitalized ships.

The digital transformation of the shipping industry and the development of MASS bring new challenges to the career requirements and education and training of seafarers. Seafarers must not only master traditional navigation skills but also acquire advanced digital competencies. However, due to their long promotion cycles and prolonged periods of isolation at sea, seafarers have limited opportunities for digital training. In addition, high internet costs and restricted bandwidth on ships[17,18] further hinder their access to new technologies, exacerbating the difficulty of promoting digital literacy. More crucially, STCW has not yet included digital competence training as an explicit requirement[19], thereby posing more challenges for seafarers in improving their digital literacy.

To bridge the gap between seafarers' current digital literacy levels and the expanding technological demands of the shipping industry, this study undertakes a detailed assessment of their digital competencies. The research evaluates seafarers' digital literacy, identifies specific skill deficiencies, and proposes strategies for competency enhancement to align with the needs of digitalized maritime operations. Guided by the global digital literacy standards of the DLGF, this study develops a tailored assessment survey that incorporates the competencies necessary for the advancement of MASS and complies with the current STCW training regulations. This survey examines multiple key dimensions of digital literacy, providing a comprehensive evaluation and highlighting critical areas for improvement. By assessing 321 seafarers through a quantitative methodology, the study analyzes the impact of variables such as educational background, sailing experience, job position, and IT training on digital literacy levels. The findings offer actionable insights for improving digital competencies among seafarers and contribute to the limited scholarly literature on digital literacy in the maritime sector.

Literature review

Digital literacy connotation

The concept of digital literacy was formally introduced by Gilster[20], who defined digital literacy as 'the ability to understand and read the true meaning of a wide range of digital resources and information displayed through a computer, with an emphasis on an individual's ability to think critically and integratively. Eshet[21] described digital literacy as the skills needed for users to be effective in the digital environment. Furthermore, Martin and Grudziecki[22] expanded this definition, interpreting digital literacy as an individual's ability to appropriately use digital tools and resources, build new knowledge, and innovate media expressions. Schäffer[23] regards it as an individual's ability to obtain and utilize information online using digital devices. Currently, global institutions primarily interpret digital literacy from the perspective of competence, as shown in Table 1. This study considers digital literacy as a comprehensive set of abilities required by citizens in a digital environment, including digital operation, acquisition, communication, security ethics, innovation, problem-solving, and others.

Digital literacy frameworks

Currently, international frameworks are primarily divided into two categories: (1) Specialized frameworks centered on digital literacy and skills, emphasizing all literacy and skills associated with digital technology use. This includes examples like the European Digital Competence Framework for Citizens (DigComp)[26], with its latest version, DigComp 2.2, released in 2022[2], and the Digital Literacy Global Framework (DLGF) developed by the United Nations Educational, Scientific, and Cultural Organization (UNESCO)[28]; (2) Comprehensive frameworks encompassing not only digital literacy and skills but also almost all other competencies required in the digital society, such as the 21st Century Learning Framework[29]. International frameworks are developed by international organizations, government agencies, enterprises, research institutions, and libraries[24,25,27], as well as individual scholars[30]. The target audiences of the frameworks are varied, with frameworks for citizens[2], students[31], and educators[32] becoming commonplace. Some frameworks also target workers in different industries, such as healthcare personnel[33] and information professionals and librarians[34]. In addition, digital literacy and skills frameworks for specific institutions have entered the public eye[35].

The DLGF (Table 2) builds upon DigComp 2.0 through a comprehensive development process that involved literature reviews, framework analysis, expert consultations, and public feedback. Designed as a versatile model applicable to diverse populations, the DLGF offers a structured set of indicators, organized across competency levels and dimensions, with detailed examples to guide implementation. Given its comprehensive approach,

Year	Organization	Concept interpretation
2012	American Library Association Institutional Repository (ALAIR)	Digital literacy is the ability to use information and communication technologies to find, understand, evaluate, create, and communicate digital information, an ability that requires both cognitive and technical skills[24]
2013	Joint Information Systems Committee (JISC)	Digital literacies—the capabilities which fit someone for living, learning and working in a digital society. Including Media literacy, Information literacy, Digital scholarship, Learning skills, ICT literacy, Career & Identify management, Communications and collaboration[25]
2013	European Commission (EC)	Digital competence involves the "confident, critical and responsible use of, and engagement with, digital technologies for learning, at work, and for participation in society. It is defined as a combination of knowledge, skills and attitudes[26]."
2017	International Federation of Library Associations and Institutions (IFLA)	To be digitally literate means one can use technology to its fullest effect -efficiently, effectively and ethically—to meet information needs in personal, civic and professional lives[27]
2018	United Nations Educational, Scientific, and Cultural Organization (UNESCO)	Digital literacy is the ability to access, manage, understand, integrate, communicate, evaluate and create information safely and appropriately through digital technologies for employment, decent jobs and entrepreneurship. It includes competences that are variously referred to as computer literacy, ICT literacy, information literacy and media literacy[28]

Table 1. Interpretation of representative concepts of digital literacy. Source: Table 1 developed by the authors.

Dimensions	Competence areas and competences
0. Devices and software operations	0.1 Physical operations of digital devices
	0.2 Software operations in digital devices
1. Information and data literacy	1.1 Browsing, searching and filtering data, information and digital content
	1.2 Evaluating data, information and digital content
	1.3 Managing data, information and digital content
2. Communication and collaboration	2.1 Interacting through digital technologies
	2.2 Sharing through digital technologies
	2.3 Engaging in citizenship through digital technologies
	2.4 Collaborating through digital technologies
	2.5 Netiquette
	2.6 Managing digital identity
3. Digital content creation	3.1 Developing digital content
	3.2 Integrating and re-elaborating digital content
	3.3 Copyright and licenses
	3.4 Programming
4. Safety	4.1 Protecting devices
	4.2 Protecting personal data and privacy
	4.3 Protecting health and well-being
	4.4 Protecting the environment
5. Problem-solving	5.1 Solving technical problems
	5.2 Identifying needs and technological responses
	5.3 Creatively using digital technologies
	5.4 Identifying digital competence gaps
	5.5 Computational thinking
6. Career-related competences	6.1 Operating specialized digital technologies for a particular field
	6.2 Interpreting and manipulating data, information and digital content for a particular field

Table 2. The overview of DLGF (Digital Literacy Global Framework)[28].Source: Table 2 developed by the authors based on the Digital Literacy Global Framework.

the DLGF serves as the foundation for constructing a digital literacy assessment questionnaire tailored to the specific needs of seafarers in this study.

Research on Seafarers' Digital Literacy

The rapid advancement of digital shipping and MASS has contributed to the widespread attention on the requirement of seafarers' digital skills from academia and the industry. Current research on seafarers' digital literacy mainly focuses on identifying their requisite digital skills. For instance, Latifa[36] analyzed the digital skills required by ship pilots and recommended the adoption of the European Digital Competence Framework (DigComp) as the digital competence framework for ship pilots. Studies conducted by Hopcraft[37], A. Oksavik et al.[38], Jo Sohyun et al.[39], and others have underscored the critical need to continually upgrade and augment seafarers' digital skills in order to uphold safety and efficiency in the shipping industry. This will not only pertain to maritime safety but also impact the sustainable development and competitiveness of the entire marine industry. Consequently, establishing a standardized digital competence framework and making ongoing skills training are currently crucial tasks for maritime education and training centers.

As for specific skills, this paper considers the classification of seafarers' required competence proposed by Cicek et al.[12] and combines the skills and competence needed for seafarers introduced by Latifa[36], Hopcraft[37], A. Oksavik et al.[38], Jo Sohyun et al.[39], Nakazawa[40], Ece Ceylani et al.[41], Shahbakhsh et al.[42], Baum Talmor et al.[43], Emad and Ghosh[44], and Muslu[45] under the development background of MASS. To meet with the future requirements of seafarers' skills, the research finally ensures 32 competencies with 4 types, as detailed in Table 3.

The STCW convention

The STCW Convention is one of the currently valid and internationally recognized conventions of seafarers' qualifications. It is an international standard of seafarers' training, certificate issuance and watchkeeping unanimously approved by its contracting states. It is officially formed for enhancing the life and property safety and protecting the marine environment, aiming to set the minimum globally recognized standard of seafarers' education and training, examination certification and safe watchkeeping to be followed. In accordance with the STCW Convention, the seafarers who apply for positions onboard shall hold corresponding certificates of competency. And the certificates must be obtained through education and training, examination and assessment (operation test) under the standard regulated by the convention. The current STCW convention mainly consists of two parts: part A and part B. Part A is mandatory and sets the minimum standard of seafarers' competencies. It specifies the requirements for general certificate levels, seafarers' competencies for specific ship types, and

Category	Competency
Technical	T1 Operations Monitoring and Analysis[12,36–38,41,42]
	T2 Equipment Operation and Control[12,36,38,39,41,42]
	T3 Maintenance and Restoration of Equipment[12,36–40,44]
	T4 Malfunction Diagnosis and Resolution[12,37–40,44]
	T5 Data Management and Application[12,36,38,41,44]
	T6 Programming[12,39,41,44,45]
Social	S1 Emotional intelligence[12,39,45]
	S2 Negotiation[12,39,41,45]
	S3 Proficiency in Linguistic Competencies[12,39,45]
	S4 Interpersonal Communication Skills[12,39,41,44,45]
	S5 Collaborative Teamwork and Synergy[12,38,39,41,44,45]
	S6 Cross-cultural Adaptability and Inclusivity[12,39,41,45]
	S7 Capacity for Concession and Collaboration[12,39,44]
	S8 Knowledge Transfer and Dissemination[12]
	S9 Leadership and Supervisory Skills[12,39,41,44]
Methodological	M1 Creativity and Innovation Capability[12,38,41]
	M2 Cognitive and Analytical Ability[12,41]
	M3 Emergency Decision-making and Handling[12,37–41]
	M4 Conflict Management and Resolution Strategies[12,39–41]
	M5 Logical Reasoning and Decision-making Processes[12,38–41]
	M6 Learning and Researching[12,38,40,41]
	M7 Complexity Management[12]
	M8 Efficiency and Productivity Optimization[12,36,38,40,42]
	M9 Proficiency in IT and Technological Affinities[12,36,38,41–44]
Personal	P1 Environmental Consciousness and Stewardship[12,38,41,43]
	P2 Safety Protocol Awareness and Compliance[12,36,37,39,43]
	P3 Legislative and Regulatory Cognizance[12,41,43]
	P4 Adaptability and Flexibility in Dynamic Contexts[12,39,41]
	P5 Ambiguity tolerance[12,39,41]
	P6 Drive for Continuous Learning[12,38,41]
	P7 Resilience and Stress Management Proficiency[12,39,41]
	P8 Sustainability and Long-term Orientation[12,41]

Table 3. Summary of Seafarers' Competencies(Seaf. Comp.). Source: Table 3 developed by the authors.

navigation areas and types, such as basic safety training, advanced firefighting training, proficiency in survival craft etc. Part B offers recommended requirements, guidelines and certain regulations, typically executed by maritime academies and Maritime Education and Training (MET) institutions. Figure 1 describes the standards of competence and assessment as presented in the STCW 2017 Edition.

Materials and methods

Study design and setting

The survey was created using the WenJuanXing platform and distributed to various shipping companies. The questionnaire link was also shared widely on social media to encourage diverse participation and reduce selection bias. Data collection took place from May 1 to June 30, 2024. Respondents were first shown a description of the questionnaire and provided informed consent by selecting "Yes" to confirm their agreement to participate. The survey collected background information, including gender, education level, current position, maritime experience, and training experience (specifically, participation in information technology training). A total of 339 responses were received, of which 321 were validated after screening. No financial incentives were offered for participation in this survey.

Questionnaire

This study designs a digital literacy assessment survey based on the DLGF framework, incorporating competencies necessary for MASS operations and aligning with STCW regulatory standards. The survey reconfigures DLGF's seven primary indicators into five key dimensions tailored to seafarers' digital literacy needs (Table 4), integrating specific skill requirements (Table 3) and STCW guidelines (Fig. 1). This structured assessment, employs a five-point Likert scale[46] , where responses range from 1 ("strongly disagree") to 5 ("strongly agree"). Higher scores indicate stronger alignment with each assessed competency. Statistical analysis was conducted using SPSS 26.

The questionnaire's five dimensions target competencies relevant to modern maritime roles. Digital general literacy, assesses foundational digital skills, such as seafarers' familiarity with digital devices and their ability

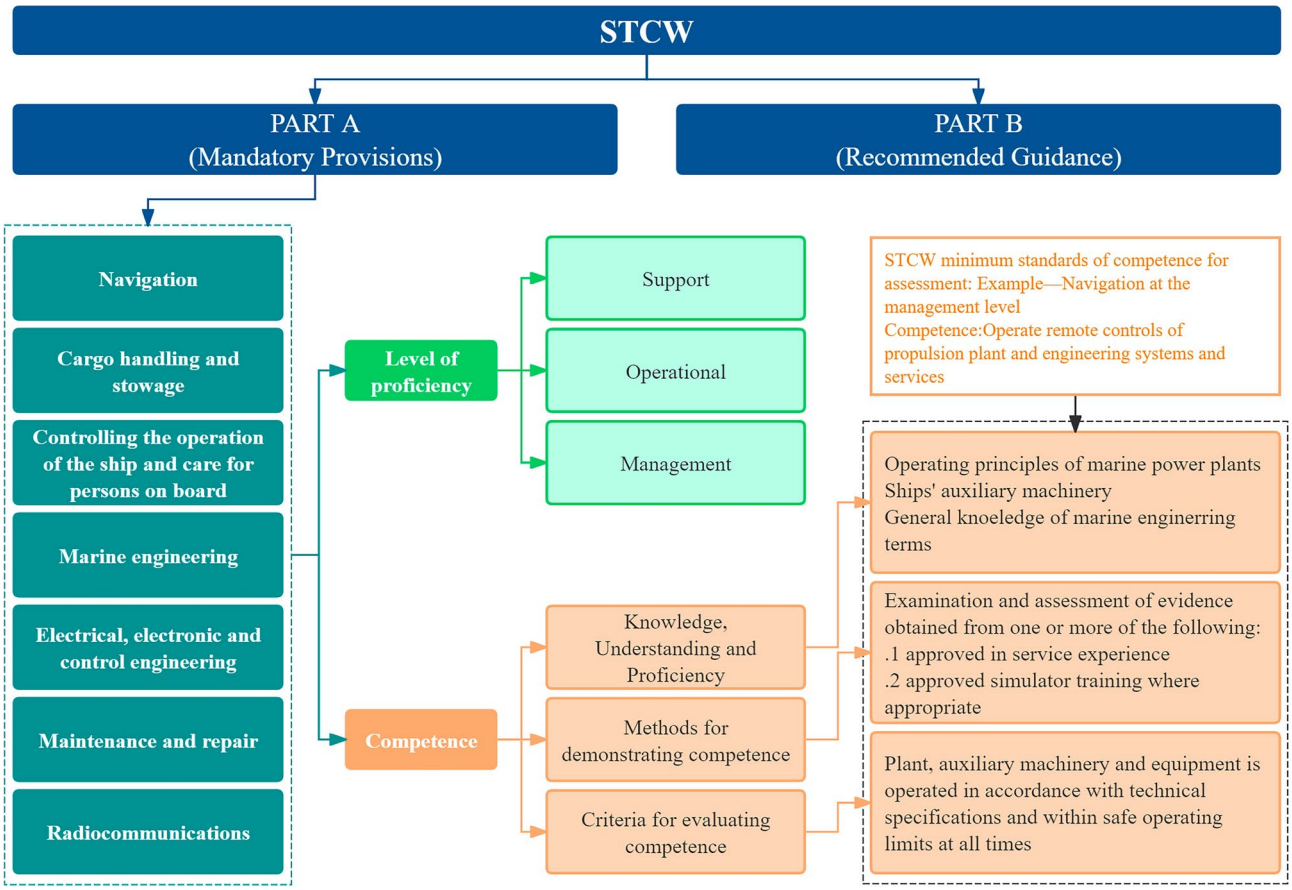

Fig. 1. Standards of Competence and Assessment in STCW 2017 Edition[19].Source: Fig. 1 developed by the authors based on the STCW(2017 Edition), pp. 3 and 47.

to locate, manage, and organize data essential for daily maritime and smart shipping operations. Digital safety and ethical literacy evaluates competencies in safeguarding personal data privacy, understanding legal responsibilities, and applying critical thinking in digital environments. Digital communication and collaboration literacy measures proficiency in utilizing digital tools to communicate, collaborate, and share content effectively. Digital content creation literacy examines the capacity to update and refine knowledge systems, as well as to generate new digital content. Digital problem-solving literacy focuses on skills needed to address challenges in intelligent shipping, such as maintaining automated systems, diagnosing remote faults, making emergency decisions, and managing safety in advanced digital contexts. Designed to reflect the competencies required of seafarers in the age of autonomous vessels, this questionnaire provides a comprehensive tool for evaluating digital literacy levels and offers insights for developing targeted digital literacy training and education initiatives in the maritime industry.

To maintain relevance, certain DLGF indicators were omitted. The indicators DLGF 0.1 and DLGF 0.2 were excluded from the questionnaire as they encompass overly broad competencies that do not specifically address maritime operating needs. Similarly, DLGF 6.2 was omitted since the entire questionnaire is focused specifically on seafarer skills, inherently addressing the domain-specific aspects of 6.2. Additionally, DLGF 5.5 has been integrated into other items within the questionnaire, ensuring coverage of relevant skills without redundancy.

Ethical issues

All procedures in studies involving human participants were performed in accordance with the ethical standards of the Ethics Committee of Shanghai Maritime University and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. The study protocol was approved by the Ethics Committee of Shanghai Maritime University. Informed consent was obtained from all individual participants included in the study.

Questionnaire reliability and validity test

Reliability and validity assessments were conducted to ensure the robustness of the questionnaire. Reliability analysis using SPSS 26 yielded a Cronbach's alpha of 0.952 for the overall survey, indicating excellent reliability. Each dimension also demonstrated strong internal consistency, with Cronbach's alpha values exceeding 0.700 (Table 5). This meets the standard for reliable measurement[47], confirming the questionnaire's suitability for further analysis.

Areas	Key competences	Reference			Description
		DLGF	Seaf. Comp	STCW	
General Information Literacy	D1 Information Acquisition	1.1	T5	–	Q1 Are you able to browse, acquire, and filter data, information, and digital content?
	D2 Information Evaluation	1.2	M2	–	Q2 Do you possess cognitive and analytical skills?
	D3 Information Management	1.3	T5	–	Q3 Do you have data management and application skills?
Digital Safety and Ethics	D4 Infrastructure Security	4.1	T3, T4	✓	Q4 Are you skilled in equipment maintenance and malfunction diagnosis?
	D5 Privacy Protection	4.2	P3	–	Q5 Do you understand how to protect personal data privacy?
	D6 Health Protection	4.3	P2	–	Q6 Are you aware of and do you comply with safety protocols?
	D7 Environmental Protection	4.4	P1	✓	Q7 Do you have environmental consciousness and stewardship skills?
Communication and Collaboration	D8 Online Communication	2.1	S2, S3, S4	–	Q8 Are you proficient in language, and do you have communication skills and negotiation ability?
	D9 Digital Sharing	2.2	S8	–	Q9 Do you have skills in knowledge sharing?
	D10 Promoting Social Inclusion	2.3	S6, P4, P5, P7	–	Q10 Do you have cross-cultural adaptability, ambiguity tolerance, and resilience against stress?
	D11 Remote Collaboration	2.4	S5, S7	-–	Q11 Do you work well in collaborative teamwork, and do you have a willingness to collaborate and compromise?
	D12 Netiquette	2.5	S1	–	Q12 Do you have emotional intelligence?
	D13 Digital Identity Management	2.6	T5	–	Q13 Are you able to manage your digital identity?
Digital Content Creation	D14 Digital Content Creation	3.1	T5	–	Q14 Do you utilize digital technology to develop digital content?
	D15 Digital Content Integration	3.2	T5	–	Q15 Can you integrate and re-elaborate digital content?
	D16 Digital Copyright and Licensing	3.3	P3	–	Q16 Do you understand laws and regulations?
	D17 Programming	3.4	T6	–	Q17 Do you have programming skills?
Problem Solving	D18 Mastering Digital Technology	6.1	T1, T2, M8	✓	Q18 Are you skilled in ship equipment operation, monitoring, and efficiency optimization?
	D19 Solving Technical Problems	5.1	M3	✓	Q19 Do you have expertise in emergency decision-making and problem-solving?
	D20 Identifying Needs and Tech Solutions	5.2	S9, M4, M5, M7	✓	Q20 Do you possess leadership, complexity and conflict management, and logical decision-making skills?
	D21 Creatively Using Digital Technology	5.3	M1, M9	✓	Q21 Are you creative, innovative, and tech-savvy?
	D22 Boosting Digital Skills	5.4	M6, P6, P8	–	Q22 Are you focused on continuous learning, sustainability, and do you have research skills?

Table 4. Seafarers' Digital Literacy Items included in the questionnaire. Source: Table4 developed by the authors.

Areas	Cronbach's α	Reference values	Items
General Information Literacy	0.765	≥ 0.800 Excellent reliability 0.700 ~ 0.800 Good reliability 0.600 ~ 0.700 Acceptable reliability < 0.600 Poor reliability	3
Digital Safety and Ethics	0.908		4
Communication and Collaboration	0.917		6
Digital Content Creation	0.811		4
Problem Solving	0.859		5

Table 5. Cronbach's alpha reliability analysis for the five areas.Source: Table 5 developed by the authors. The item counts (3, 4, 6, 4, and 5) refer to the number of questions within each dimension of the questionnaire.

For construct validity, the Kaiser–Meyer–Olkin (KMO) test returned a value of 0.944, and Bartlett's test of sphericity was significant ($\chi^2 = 5635.966$, df = 231, $p < 0.001$), confirming the data's appropriateness for factor analysis[48].

Results

Assessment of Seafarers' Digital Literacy Levels

In this study, a total of 339 questionnaires were collected, of which 321 were valid, with a validity rate of 94.7%. This effective sample size not only meets the requirements for data analysis but also significantly exceeds ten times the number of questionnaire items, thereby ensuring the robustness of the data analysis. Table 6 details the sample attribute.

Upon conducting a frequency analysis of the collected questionnaire samples, it was observed that the majority of the seafarers in the sample are male, accounting for 98.4%, indicating a significant gender imbalance in the shipping industry, with males being predominant. In terms of digital information technology training, nearly half of the seafarers had participated in, reflecting the increasing significance of digital information

Statistical factors	Options		Number of participants	Percentage
Participation in Information Technology Training	Yes		152	47.4%
	No		169	52.6%
Gender	Male		316	98.4%
	Female		5	1.6%
Education Level	Master's/Doctoral		16	5.0%
	Bachelor's		111	34.6%
	Other		194	60.4%
Position/Title	Master		23	7.2%
	Deck Department	Chief Officer	44	13.7%
		Second Officer	55	17.1%
		Third Officer	14	4.4%
		Seaman	17	5.3%
	Engine Department	Chief Engineer	44	13.7%
		First Engineer	50	15.6%
		Second Engineer	53	16.5%
		Motorman	11	3.4%
	Steward Department		10	3.1%
Maritime Experience	more than 20 years		35	10.9%
	16–20 years		40	12.5%
	11–15 years		122	38.0%
	5–10 years		94	29.3%
	less than 5 years		30	9.3%

Table 6. Sample characteristics (N = 321). Source: Table 6 developed by the authors.

technology applications in the contemporary shipping industry and the evolving requirements for seafarers' digital competencies. Among the five female seafarers, three had participated in information technology training. In terms of educational background, the result shows that seafarers with bachelor degree account for 34.6% while those with master or doctor degree only account for 5.0%, and 60.4% are seafarers with other diplomas, suggesting that the maritime industry may value practical experience and skills much over higher education. The sample covers seafarers with various positions and titles, from logistics management personnel of service department to captains, they all took participate in this survey. In terms of sailing experience, about 38.0% seafarers interviewed have 11 to 15 years of sailing experience while 29.3% seafarers have 5 to 10 years of that, which indicates that most of the interviewed seafarers have rich working experience onboard.

Analysis of overall digital literacy level of seafarers

To comprehensively assess the digital literacy level among seafarers, this section computes the mean values of literacy in each dimension. Furthermore, standard deviation, skewness, and kurtosis are calculated to gain insights into the overall characteristics of the data. Detailed findings can be referenced in Table 7.

The data presented indicated that the score of digital literacy for seafarers surveyed was 3.47, which fell between "average" and "satisfactory.", suggesting that the digital literacy of the surveyed seafarers was at a medium level. The data distribution exhibited negative skewness and positive kurtosis, signifying it was left-skewed and leptokurtic, which could imply a disparity among seafarers interviewed, with some excelling in various areas while others demonstrating relatively weaker performance.

Digital General Literacy: Seafarers' scores in information acquisition and management were slightly lower than the overall rating, suggesting a need for further skill enhancement in these areas. However, their information assessment scores aligned with the overall mean, showing these seafarers interviewed have some competencies in that.

Digital Security and Ethics Literacy: Seafarers perform well in privacy protection, as their scores are comparable to the overall rating. However, scores in infrastructure security, health protection, and environmental protection fall below the overall mean, indicating a need for improvement in these areas.

Digital Communication and Collaboration Literacy: Seafarers exceed the overall rating in online communication, social inclusion, remote collaboration, netiquette, and digital identity management etc. Particularly high scores in netiquette and digital identity management highlight their strong performance in these areas.

Digital Content Creation Literacy: Seafarers' scores above the overall rating in digital content creation and digital copyright and licensing, reflecting their potential in these areas. However, their scores in digital content integration and programming are lower, with programming scores falling below 3 points, indicating a need for improvement.

Digital Problem-Solving Literacy: Seafarers demonstrate strong performance in ship software and hardware operation and identifying numbers. However, their scores are below the overall mean in solving technical issues,

Areas	Key competences	Mean	SD	Skewness	Kurtosis
General Information Literacy	D1 Information Acquisition	3.35	0.83	− 0.49	0.13
	D2 Information Evaluation	3.47	0.75	− 0.50	0.63
	D3 Information Management	3.42	0.76	− 0.43	0.77
Digital Safety and Ethics	D4 Infrastructure Security	3.36	0.92	− 0.31	-0.10
	D5 Privacy Protection	3.48	0.86	− 0.25	0.12
	D6 Health Protection	3.44	0.88	− 0.34	0.05
	D7 Environmental Protection	3.46	0.85	− 0.46	0.37
Communication and Collaboration	D8 Online Communication	3.71	0.83	− 0.48	0.45
	D9 Digital Sharing	3.46	0.80	− 0.18	0.37
	D10 Promoting Social Inclusion	3.57	0.76	− 0.43	0.56
	D11 Remote Collaboration	3.55	0.76	− 0.39	0.62
	D12 Netiquette	3.74	0.81	− 0.55	0.57
	D13 Digital Identity Management	3.77	0.82	− 0.59	0.61
Digital Content Creation	D14 Digital Content Creation	3.57	0.80	− 0.32	0.36
	D15 Digital Content Integration	3.35	0.88	− 0.25	0.06
	D16 Digital Copyright and Licensing	3.49	0.81	− 0.35	0.42
	D17 Programming	2.75	1.12	0.09	− 0.97
Problem Solving	D18 Mastering Digital Technology	3.67	0.95	− 0.73	0.32
	D19 Solving Technical Problems	3.33	0.86	− 0.23	0.26
	D20 Identifying Needs and Tech Solutions	3.45	0.79	− 0.32	0.47
	D21 Creatively Using Digital Technology	3.44	0.78	− 0.14	0.26
	D22 Boosting Digital Skills	3.57	0.78	− 0.34	0.56

Table 7. Table of seafarers' digital literacy levels across five areas. Source: Table 7 developed by the authors.

determining needs and technological responses, and creatively using digital technology, indicating areas for enhancement.

In conclusion, seafarers exhibit excellent digital literacy in numerous areas, particularly in online communication, netiquette, digital identity management, digital content creation, and the operation of ship software and hardware. Nevertheless, the subpar performance in programming skills suggests a necessity for enhancement in this domain. The characteristics of the data reveal that although the digital literacy levels of seafarers are generally consistent, there exist individuals who demonstrate exceptional skills in specific areas.

Differential analysis of seafarers' digital literacy

To investigate the variances in digital literacy amongst seafarers, this study employed the secondary indicators of the five dimensions of digital literacy as dependent variables, with seafarers' education level, sailing experience, job position, and participation in digital information technology training as independent variables for empirical analysis. Utilizing SPSS 26 software, T-tests and one-way analysis of variance (ANOVA) were carried out on independent samples with different background variables. These statistical methods were primarily utilized to determine whether diverse socio-demographic characteristics at various levels have a notable impact on the digital literacy of the respondents. The independent sample T-test was used for comparative analysis of dichotomous variables, whereas one-way ANOVA was employed for variables with three or more categories.

The results show that for seafarers with varying education levels, sailing experience, and job positions, P values of their digital literacy scores on five dimensions all exceed 0.05, suggesting no substantial differences in digital literacy scores among the surveyed seafarers in these areas. However, a significant disparity is observed among seafarers who have participated in digital information technology training and those who have not, as elaborated in Table 8.

In Table 8, seafarers who participated in digital information technology training are divided into two groups and Levene's test is utilized to judge the homogeneity of variance. If the significance (Sig) value surpasses 0.05, the variance is considered homogeneous, and the first row of t-test results is referred to; if the Sig value is below 0.05, the variance is deemed non-homogeneous, and the second row of t-test results is consulted. The Sig value of the t-test determines the significance of the difference between the two sample groups; a value above 0.05 indicates no significant difference, while a value below 0.05 signifies a significant difference. Based on the data in Table 8, it can be inferred that there are no significant differences between seafarers who have and have not undergone digital information technology training in five dimensions: information acquisition (D1), promoting social inclusion (D10), netiquette (D12), digital identity management (D13), and digital copyright and licensing (D16). Significant differences are observed in the remaining aspects. Furthermore, a t-value exceeding 0 indicates that seafarers who have undergone digital information technology training significantly outperform those who have not in terms of digital literacy.

Areas		Levene's test for equality of variances		t-test for equality of means						
									95% CI of the difference	
		F	Sig	t	df	Sig (2-tailed)	Mean difference	SE	LB	UB
General Information Literacy	D1	3.122	0.078	1.349	319	0.178	0.125	0.092	− 0.057	0.306
				1.346	312.723	0.179	0.125	0.093	− 0.058	0.307
	D2	3.210	0.074	2.479	319	0.014	0.206	0.083	0.043	0.370
				2.465	305.198	0.014	0.206	0.084	0.042	0.371
	D3	1.180	0.278	3.538	319	0.000	0.295	0.083	0.131	0.459
				3.540	316.093	0.000	0.295	0.083	0.131	0.459
Digital Safety and Ethics	D4	4.121	0.043	3.781	319	0.000	0.382	0.101	0.183	0.580
				3.834	311.018	0.000	0.382	0.100	0.186	0.578
	D5	1.018	0.314	2.429	319	0.016	0.232	0.096	0.044	0.421
				2.445	318.893	0.015	0.232	0.095	0.045	0.420
	D6	0.240	0.625	3.245	319	0.001	0.315	0.097	0.124	0.507
				3.262	318.983	0.001	0.315	0.097	0.125	0.506
	D7	3.210	0.074	3.668	319	0.000	0.342	0.093	0.159	0.526
				3.711	314.753	0.000	0.342	0.092	0.161	0.524
Communication and Collaboration	D8	3.734	0.054	2.881	319	0.004	0.263	0.091	0.083	0.442
				2.891	318.511	0.004	0.263	0.091	0.084	0.442
	D9	0.148	0.700	3.319	319	0.001	0.293	0.088	0.119	0.467
				3.326	317.748	0.001	0.293	0.088	0.120	0.466
	D10	0.739	0.391	1.604	319	0.110	0.135	0.084	− 0.031	0.301
				1.609	318.082	0.109	0.135	0.084	− 0.030	0.301
	D11	1.729	0.189	2.992	319	0.003	0.252	0.084	0.086	0.417
				3.007	318.938	0.003	0.252	0.084	0.087	0.416
	D12	4.660	0.032	1.361	319	0.174	0.123	0.090	− 0.055	0.300
				1.367	318.877	0.172	0.123	0.090	− 0.054	0.300
	D13	5.942	0.015	1.155	319	0.249	0.106	0.092	− 0.075	0.288
				1.164	318.300	0.245	0.106	0.091	− 0.073	0.286
Digital Content Creation	D14	1.581	0.210	2.233	319	0.026	0.198	0.089	0.024	0.373
				2.243	318.802	0.026	0.198	0.088	0.024	0.372
	D15	1.767	0.185	3.275	319	0.001	0.318	0.097	0.127	0.509
				3.284	317.961	0.001	0.318	0.097	0.127	0.508
	D16	1.638	0.201	1.743	319	0.082	0.158	0.091	− 0.020	0.337
				1.756	318.677	0.080	0.158	0.090	− 0.019	0.335
	D17	13.960	0.000	4.677	319	0.000	0.567	0.121	0.329	0.806
				4.737	313.222	0.000	0.567	0.120	0.332	0.803
Problem Solving	D18	6.900	0.009	2.160	319	0.032	0.227	0.105	0.020	0.434
				2.182	316.657	0.030	0.227	0.104	0.022	0.432
	D19	0.022	0.883	3.338	319	0.001	0.316	0.095	0.130	0.502
				3.367	317.996	0.001	0.316	0.094	0.131	0.501
	D20	0.616	0.433	3.488	319	0.001	0.304	0.087	0.133	0.476
				3.515	318.541	0.001	0.304	0.087	0.134	0.474
	D21	0.150	0.699	3.141	319	0.002	0.272	0.087	0.102	0.442
				3.148	317.530	0.002	0.272	0.086	0.102	0.442
	D22	2.932	0.088	2.881	319	0.004	0.248	0.086	0.079	0.418
				2.901	318.834	0.004	0.248	0.086	0.080	0.417

Table 8. Independent samples test for training participation. Source: Table 8 developed by the authors. Note: In each cell, the first line indicates "assuming equal variances," and the second line indicates "assuming variances are not equal."

Discussion

This study assesses the digital literacy levels of Chinese seafarers in the context of advancing digital shipping technologies. Guided by the UNESCO's DLGF and aligned with current STCW training regulations, a tailored assessment survey was developed to capture the competencies essential for the transition to MASS. The survey

was administered to 321 Chinese seafarers, providing a comprehensive overview of their digital literacy levels. The questionnaire survey revealed that seafarers' overall digital literacy level is moderate, with strengths in online communication, netiquette, and digital identity management, but there is still a need for improvement in programming skills for seafarers. Moreover, the survey found no significant differences in digital literacy among seafarers with varying educational backgrounds, sailing experience, and job positions. But those who had undergone digital information technology training scored significantly higher in most dimensions compared to those who had not.

The findings of this paper align with existing literature in several aspects but also present some disparities. The research reveals a positive correlation between participation in digital information technology training and digital literacy levels, which is consistent with current research results. As Atmojo et al.[49] argue in their study that digital literacy training enhances teachers' information literacy skills, notably the ability to identify potential information sources and execute search strategies. This finding aligns with the results of our research, which posit a positive correlation between involvement in information technology training and an increase in digital literacy. Similarly, Bhat[50] underscores the significant role of online learning platforms in bolstering students' information fluency: a vital component of digital literacy. Chiu Thomas KF et al.[51] corroborate this assertion, presenting evidence that the relationship between perceived support and digital literacy is positively impacted by technology learning support, with needs satisfaction serving as a partial mediator. Furthermore, a systematic literature review by Choudhary and Bansal[52] suggests that digital literacy training programs not only augment digital skills but also promote better personal-level outcomes across several areas such as health, leisure, and self-actualization. This underscores the value of information technology training in expanding digital literacy and its wider effect on individuals' lives. Malik Muh Tahir et al.[53] finally stress the importance of ICT-based educational innovation policies in tertiary institutions, which boost the digital literacy abilities of the academic community. This insight aligns with our research, reinforcing the positive correlation between participation in information technology training and enhanced digital literacy levels. Overall, these studies validate our research conclusion by offering persuasive evidence for the positive correlation between involvement in information technology training and increased digital literacy levels, emphasizing the pivotal role of structured training and support in fostering digital literacy skills.

This study found no marked distinctions in the digital literacy levels of seafarers, irrespective of their diverse educational backgrounds, maritime experience, or job roles. Contrary to initially projected hypotheses, the study uncovered no significant correlation between seafarers' educational level and their digital literacy. This discovery contradicts several recent studies that propose a positive correlation between advanced education and improved digital literacy skills. For instance, Shopova[31]asserted that advanced education promotes digital literacy skills, fostering both the efficiency and effectiveness of learning processes and aiding adjustment to the evolving labor market. In congruence, Gutierrez-Angel et al.[54] advocated that advanced education elevates digital literacy by solidifying competencies in digital writing, reading, database comprehension, content design, and web publishing. Kaya and Korucuk[55] disclosed that even though the digital literacy levels of university students were low, significant differences were observed in relation to their grade point average, social network usage, and their parents' educational status. Meanwhile, Vodă Ana Iolanda et al.[56] proposed that besides the areas of creativity and problem-solving, varying education levels significantly impact students' digital literacy skills. They posited that advanced educational levels notably influence digital literacy skills and that communication, critical thinking, problem-solving and technical skills are more prominent among economics and social sciences students as compared to humanities students.

This study's observation, which revealed the lack of a notable correlation between the educational levels of seafarers and their digital literacy, could potentially be ascribed to several distinctive facets of the maritime industry, in addition to the specific operating conditions for seafarers.

Firstly, the unique nature of the maritime industry presents significant challenges to the efficacy of traditional higher education systems in fostering seafarers' digital literacy. Unlike other industries, the maritime sector places a high emphasis on practical skills and hands-on experience, which are often difficult to develop effectively through traditional education methods. In this kind of industry environment, a considerable gap exists between traditional academic education, dominated by theoretical knowledge, and vocational skills[57,58], which could hinder the development of professional competencies for seafarers, including digital literacy.

Secondly, despite receiving traditional education, seafarers face challenges in catching up with the rapid development of digital technologies due to the slow updating of educational curricula. Higher education institutions, in particular, are under great pressure to continually adjust their courses in order to align with the latest digital technologies and tools[59–61]. Nevertheless, these institutions may struggle to fully meet the specific digital competencies for seafarers required by modern ships. As working long-term onboard, the unique working environment of seafarers exacerbates this challenge, resulting in their relatively isolation from the outside world, which also greatly limits their access and application to the latest digital technologies and equipment. Additionally, the specific communication environment onboard, characterized by high Internet costs and limited network bandwidth[17,18], further impedes seafarers' ability to acquire and learn new digital technologies.

Finally, when investigating the factors that impact seafarers' levels of digital literacy, it appears that personal qualities and subjective initiative may wield greater influence than educational background. Specifically, factors such as seafarers' individual interests, self-learning ability, and learning motivation may have a greater effect on shaping their digital literacy. Firstly, personal interest plays a fundamental role in the development of digital literacy[62]. Seafarers with a strong interest in digital technologies are more likely to actively explore and learn about new technologies, thus continuously improving their digital competencies. This underlying motivation may lead them to develop more digital skills in informal learning settings than through formal education. Secondly, self-learning ability increasingly occupies the important position in today's digital society. Given the prevalence of online courses, tutorials, and other digital learning resources, seafarers with strong self-learning

abilities can more effectively utilize them to continuously renew and expand their digital knowledge base[63,64]. This self-motivated learning approach, to some extent, diminishes the decisive impact of traditional education on digital literacy. Moreover, personal learning motivation[65] plays a pivotal role in the acquisition of digital skills. Faced with the pressure of digital transformation in the shipping industry, seafarers with a strong drive for self-improvement are more likely to actively seek learning opportunities and continuously update their digital skills. This self-motivated learning approach may be more effective in enhancing digital literacy levels than passive reception of formal education.

To be noted, this study has two limitations: Firstly, it assumed the seafarer group as homogeneous. The digital literacy framework for seafarers, as proposed in this study, adopted a holistic perspective, overlooking the potential differences in requirements of digital skills for seafarers with various job positions. In fact, various positions for seafarers may exist obvious differences in their working content, applied technologies and paths for career development, which could lead to diverse requirements and application patterns for their digital skills. Secondly, the sample taken in this study has geographical limitation: this paper only surveyed Chinese seafarers, ignoring the factors of nationalities, cultural background and geographical origins for the seafarer participants, which to some extent limits the universality and external validity of the research results. Seafarers from different countries and regions may encounter significantly different working environments, cultural backgrounds, education systems, and technology access levels, all of which can profoundly influence their digital literacy requirements and levels.

Recommendations

Future researches will be conducted from the aspects below: Expand the sample range: to include seafarers from diverse nations and regions so as to enhance the universality and transferability of the research results. Segment the seafarer group: to segment the seafarers according to their job positions and investigate the requirements of digital literacy levels for seafarers on varying positions. This stratified analysis will facilitate the development of more tailored educational and training programs for seafarers, thus fitting with the specific requirements for different types of seafarers. Conduct comparative researches: to conduct comparative researches on seafarers across various countries, regions, or job positions, unveiling the disparities and similarities in the requirements and levels of digital literacy for seafarers. Utilize mixed methods: to combine quantitative and qualitative approaches in the research for yielding more comprehensive and in-depth data. For example, to collect large-scale data by using questionnaire survey and to delve into the specific phenomena and cases by conducting focused interviews and case study.

The disconnect between seafarers' education levels and digital literacy underscores the pressing need for comprehensive reform in MET institutions. It also necessitates collaborative efforts from various stakeholders in the shipping industry to nurture high-quality maritime talents that align with the demands of the digital era.

- Enhance industry-university-research cooperation to bridge the gap between theoretical teaching and practical needs.
- MET institutions should periodically update their courses to keep up with the latest industry advancements.
- Incorporate digital literacy into the STCW Convention to standardize and prioritize digital literacy training for seafarers.
- Improve communication conditions of vessels to foster a better online learning environment for seafarers.
- Strengthen on-the-job training to provide continuous learning opportunities for seafarers.
- Training programs for seafarers should focus on stimulating learners' interest in digital technologies, rather than merely imparting knowledge.
- Cultivate students' self-learning abilities, empowering them to continually update their digital skills throughout their future careers.

Data availability

The data underlying this article will be shared upon reasonable request to the corresponding author.

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Junhua Li wrote the main manuscript text. Wenhai Dong conducted the formal analyses. All authors conceptualized, reviewed, and edit the manuscript. The authors are responsible for the content of this publication.

Competing interests

The authors declare no competing interests.

Additional information

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