Understanding Maritime Subjects in Vocational High Schools through Online Learning

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Abstract

This study explores the effectiveness of online learning for maritime subjects in Indonesian vocational high schools, focusing on how the rapid advancement of information technology has reshaped education in this unique field. Using a quantitative approach with 275 respondents, the research analyzes key factors that influence students' understanding of maritime subjects, such as digital literacy, motivation, and their perceptions of the effectiveness of online learning. The findings indicate moderate levels of both digital literacy and motivation for online learning, with flexibility being the most appreciated benefit. However, challenges related to social isolation were also noted. A predictive model developed during the research accounts for 43% of the variance in comprehension of the subject matter, identifying digital literacy and perceived online learning effectiveness as the strongest predictors. Additionally, the grade level of students significantly influenced their comprehension scores. This study emphasizes the need to integrate digital skills training and to employ engaging instructional strategies to enhance learning outcomes. Future research could investigate the use of immersive technologies, such as virtual reality or simulations, to better support practical skills development in maritime education, ensuring that students are well-prepared for real-world challenges in the maritime industry.

Keywords: *Digital Literacy; Maritime Education; Online Learning; Student Motivation; Vocational High Schools*

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Introduction

Information and communication technology development has brought significant changes across various aspects of life, including the education sector (Simmons & McLean, 2020)). Online learning, or e-learning, has become an increasingly popular alternative for delivering educational content, particularly in the digital age. Vocational high schools, which serve as educational institutions that prepare students for careers, have undergone this transformation, including in the maritime sector, which stands out for its distinctive and intricate characteristics (Heirs & Manuel, 2021) (Yuen et al., 2022). The maritime industry is a crucial sector globally, requiring a skilled and knowledgeable workforce. Learning in this field involves various technical aspects, from ship design and construction to navigation and propulsion systems. In the context of vocational high schools, maritime subjects aim

to equip students with the fundamental knowledge and skills this industry requires (Martes, 2020; Wang et al., 2021; Tusher et al., 2023).

Nonetheless, maritime education at the vocational high school level faces various challenges. One key challenge is the limited access to expensive practical facilities and equipment, which schools often struggle to provide (Beneroso & Robinson, 2022) and (Malyuga & Petrosyan, 2022). Furthermore, the rapid technological advancements in the maritime industry necessitate more adaptable curricula and teaching methods (Yang et al., 2022).

Online learning exhibits substantial promise to mitigate some of these challenges in this context. E-learning platforms allow students to access extensive and engaging learning resources, including virtual simulations and demonstration videos that can augment hands-on instruction (Theobald & Bellhäuser, 2022). Furthermore, online learning facilitates remote collaboration with maritime industry professionals and experts, enhancing students' learning experiences (Netchaeva et al., 2022).

While the efficacy of online instruction in technical domains such as maritime studies continues to be a topic of scholarly discourse, existing research has yielded ambiguous findings. For example, one study by X. Chen et al. (2017) determined that e-learning can augment students' conceptual grasp of maritime engineering subjects. Conversely, research by Syed Abd Halim et al. (2023) suggests that hands-on practical training remains crucial for developing specific technical competencies.

Furthermore, some factors also affect students' capacity to comprehend online learning materials. Access to technology, digital skills, and self-directed learning motivation are some variables that can impact the effectiveness of online learning Almomani et al. (2023) and Demir et al. (2023). In the context of vocational high schools in Indonesia, where digital divides remain a pertinent issue Onitsuka et al. (2018) and Mathana & Galdolage (2023), these factors become increasingly relevant to investigate. This digital divide, encompassing both access to technology and digital literacy skills, can significantly hinder the implementation of online learning in maritime vocational education. Addressing these disparities is crucial for ensuring equitable access to quality education in specialized fields like maritime studies, particularly in developing countries like Indonesia where infrastructure and economic disparities can lead to unequal access to digital resources. Investigating these factors can provide valuable insights into developing more inclusive and effective online learning strategies for maritime vocational education.

While several studies have been conducted on online learning in vocational high schools and engineering fields in general, there remains a gap in the specific understanding of the effectiveness of online learning for maritime subjects at the vocational high school level (Pipchenko & Kovtunenko, 2020). Previous research has focused on higher education or engineering fields in general. In contrast, the unique characteristics of marine learning at the vocational high school level have not been explored in depth.

Accordingly, this research aims to fill this gap by investigating vocational high school student's ability to understand maritime subjects through online learning. Specifically, the study will explore the factors influencing student comprehension, the challenges faced, and the potential and limitations of online learning in this context. Furthermore, the research findings can provide valuable input for educational policymakers in designing curricula and learning infrastructure that support the utilization of digital technology in vocational education, particularly in the maritime field. Additionally, the study will identify strategies to enhance vocational high school students' understanding and readiness for the maritime industry.

Literatur Review
Online Learning in Vocational Education
Online learning, including vocational education, has become integral to the modern educational landscape. According to several studies (Kuputri, 2020; Wang et al., 2021; Li et al., 2022; Liu & Yu, 2023), e-learning offers flexibility and accessibility that can enhance student engagement in the learning process. Furthermore, research on implementing e-learning in vocational schools in Southeast Asia has found that online platforms can increase student involvement compared to traditional methods (Tay et al., 2021).

Challenges and Opportunities of Online Learning in Engineering Disciplines
Technical disciplines, such as maritime studies, have distinct characteristics that can hinder the effective implementation of online learning. Studies by Rehman (2023) and Ahmad et al. (2023) have

identified the need for hands-on experience and laboratory practice as a critical obstacle to the full adoption of e-learning in these fields. However, using virtual simulations and remote laboratories has somewhat mitigated this challenge. The existing literature suggests that in the maritime industry context, online learning can improve vocational high school students' conceptual grasp of marine-related subjects. However, researchers have also stressed the continued need for hands-on practical instruction to develop specific technical competencies Pipchenko & Kovtunenko (2020). Consequently, a blended learning approach integrating both online and in-person teaching methods may represent an effective solution to address these challenges. Further, a meta-analysis of 50 studies by Alshammary & Alhalafawy (2023) has demonstrated that online learning can enhance vocational high school students' conceptual understanding of technical subjects. The researchers found that students enrolled in online courses exhibited a 15% improvement in theoretical comprehension compared to traditional instruction. However, face-to-face learning still maintained a 10% advantage for the development of practical skills.

Online Learning in the Maritime Discipline

The maritime industry and associated educational initiatives have explored diverse, innovative approaches, including digital simulators, virtual and augmented reality technologies, and interactive multimedia resources. Research suggests these methods can bolster students' technical competencies, conceptual understanding, and engagement (Renganayagalu et al., 2019). However, the integration of modern teaching practices in maritime education and training continues to be impeded by the need to align with predominantly traditional regulations and standards (Basak, 2017) (Pipchenko & Kovtunenko, 2020).

Existing research has advocated for a thoughtful blended learning approach that strategically integrates online and face-to-face instruction to enhance learning outcomes in maritime studies (Y. Lau & Ng, 2015). This hybrid model delivers theoretical knowledge through digital platforms while preserving the essential hands-on practical training component within a physical setting. Although implementing blended learning in maritime education and training institutions may face challenges related to legal frameworks, infrastructure, and human resources, the findings suggest the potential for collaborative efforts between institutions to optimize costs and deliver more effective training programs (Z. Chen et al., 2021) and (Zgraggen, 2021).

Factors Affecting the Effectiveness of Online Learning

Given the rapid technological progress, applying digital literacy in academic settings can enhance students' long-term learning. Digital literacy extends beyond the ability to operate software and digital devices, encompassing the social and ethical aspects (Reddy et al., 2022; Le et al., 2022; Nguyen & Habók, 2024). Teachers and students require fundamental skills and advanced expertise to effectively interpret digital information (Wahjusaputri & Nastiti, 2022). Research on implementing MOOC models has shown more significant learning gains than traditional instructional methods. In technical and engineering fields, there is no statistically significant difference in effectiveness between blended learning and fully online learning approaches (Dalipi et al., 2016). In contrast, for disciplines in the humanities where communication is a crucial aspect of learning, technology-enabled blended learning tends to yield better results (Larionova et al., 2018).

Additionally, motivation and self-directed learning play crucial roles. An ongoing study involving 1,000 vocational high school students has shown that students with higher levels of self-directed learning exhibited 35% better performance in online learning than their peers with lower levels of self-directed learning (Theobald & Bellhäuser, 2022).

Advancements in education and technology can potentially enhance the quality of educators and students in the evolving world. Appropriate learning models and media can improve the effectiveness and creativity of instruction, especially in vocational high schools that require a balance of theory and practice, as well as the interaction and guidance students need. Using online learning models in vocational high schools can potentially improve student learning outcomes and quality (Silvana et al., 2021).

Access to technology and infrastructure is also crucial, especially in developing countries. Okoye et al. (2023). Digital technology and literacy can enhance the transformation of teaching and learning in higher education institutions (HEIs). This study shows how digital technology has been used to improve the learning and teaching process in higher education, as well as the problems

and issues arising from it. These problems and issues may not be appropriately solved in all higher education institutions.

Instructional Design Approaches for Online Learning in Technical Disciplines

Appropriately instructional design is crucial given the complexity of technical subjects like maritime studies. Research has emphasized the importance of a learner-centered, interactive, and competency-based approach and project-based learning in distance education to enhance motivation, learning outcomes, and competency development (Malyuga & Petrosyan, 2022).

This model, which combines elements of virtual collaboration, interactive simulation, and performance-based assessment, has improved students' understanding of complex concepts compared to traditional e-learning approaches (El-Sabagh, 2021). Additionally, S. Y. Chen & Wang (2021) highlights the significance of personalization in online learning for technical fields. By implementing adaptive systems that tailor content and pacing to individual student needs, they have observed increased knowledge retention and higher levels of student satisfaction.

Evaluating the Effectiveness of Online Learning in Vocational High Schools

Various studies have attempted to evaluate the effectiveness of online learning in vocational high schools. Online learning has shown results on par with face-to-face instruction for theoretical subjects (Shah & Arinze, 2023). However, for practical courses, face-to-face learning still maintains a comparative advantage (Ebner & Gegenfurtner, 2019). Conversely, other researchers have argued that with appropriate instructional design, online learning can be equally effective as face-to-face, even for practical subjects (Syed Abd Halim et al., 2023) and (Owolabi et al., 2024).

Challenges in Implementing E-learning in Vocational High Schools

Despite the significant potential of e-learning in vocational high schools, its implementation faces various challenges (Hill et al., 2021). The COVID-19 pandemic has compelled universities with limited digital expertise to rapidly transition to online teaching and assessment. This transition has created new issues and presented more opportunities for contract cheating and diversification of such services. Online examinations offer alternate avenues for contract cheating, and the literature indicates that students are likely to engage in academic dishonesty during online assessments if given the opportunity (Lancaster & Cotarlan, 2021) and (Rundle et al., 2023). As universities and instructors adapted new teaching approaches and assessment methods in response to the pandemic, opportunistic contract cheating services have offered $50 COVID-19 discounts, allowing students to either take their online exams or receive direct assistance from "professionals" when completing them (Arnold, 2022).

Besser et al. (2022) The findings indicate that while most students responded negatively to the compulsory transition to online learning due to the pandemic, those with greater adaptability tended to exhibit more positive responses across various aspects. Researchers also found a weak link between personal beliefs and specific reactions to online learning, mediated by the ability to adapt. Further analysis revealed that students who felt a greater sense of ownership and importance within their learning environment displayed more positive reactions and better adaptability.

Gaps in the Literature and Future Research Directions

Although numerous studies have been conducted on online learning in general secondary schools, there remains a paucity of specific research examining the effectiveness of e-learning for teaching business-related subjects at the vocational high school level (Vaskova Kjulavkovska et al., 2022). However, adaptability in the online learning context can be cultivated through appropriate learning processes. Engaging in activities that foster self-awareness, exploration of the learning environment, and goal-setting can facilitate the development of adaptability among students.

Furthermore, technological advancements have transformed the scientific data landscape, with large datasets and high refresh rates becoming commonplace across various scientific fields (Rosenberg et al., 2022). This has implications for educational sciences, as these technologies hold significant potential to enhance the quality and effectiveness of distance learning in complex technical domains by enabling students to engage with data in more sophisticated ways.

Methodology

This study employed a quantitative approach to investigate vocational high school students' abilities to comprehend maritime-related subjects through online learning. This method was selected to enable comprehensive statistical analysis and generalize the sample's findings to a broader population.

The target population for this study was vocational high school students majoring in maritime studies in Indonesia. A stratified random sampling method was employed to ensure adequate representation. Stratification was based on geographical regions to ensure diversity across different areas. The sample size was determined using the Slovin formula, with a 95% confidence level and a 5% margin of error. Based on the estimated total population of 10,000 SMK maritime students in Indonesia, the required sample size was 370 respondents. However, the target was set at 400 respondents to anticipate potential non-response and invalid data. Data collection was conducted through an online survey using the Google Forms platform. The questionnaire was distributed through partnerships with schools and associations of vocational high school teachers in the maritime field, and the data collection period spanned 2 months, from January to February 2024.

This study's primary data collection tool was an online survey that included demographic characteristics, digital literacy, motivation for online learning, perceived effectiveness, and comprehension of maritime-related subjects. The survey utilized 5-point Likert scales, except for the comprehension assessment, which employed a multiple-choice format. The instrument's content validity was evaluated by a panel of experts comprising 3 academics in the field of vocational education and 2 industry practitioners in the maritime sector. Construct validity was examined using confirmatory factor analysis. The reliability of the instrument was assessed using Cronbach's alpha coefficient. A pilot test with 50 respondents demonstrated good reliability for all scales.

The collected data were analyzed using SPSS version 28. The analyses included Descriptive statistics to characterize the sample and distribution of responses. We used exploratory factor analysis to find the most critical factors that affect students' comprehension in online learning, multiple regression analysis to find the connections between independent and dependent variables, analysis of variance to see how different groups of students understand things differently based on demographic factors, and structural equation modeling to check the idea that different factors are connected to student's comprehension levels.

Results and Discussion
Result

The study involved 275 participants, with the majority being male and predominantly in the 17-18 age range. The distribution of respondents across grade levels was reasonably even, with a slight overrepresentation of 11th-grade students. The majority of the respondents hail from the island of Java, reflecting the geographic distribution of the population of vocational high school maritime students in Indonesia. Table 1 presents the demographic characteristics of the respondents. Chi-square analysis revealed no significant differences in the distribution of gender and grade level across regions, indicating a well-balanced sample.

Table 1. Demographic Characteristics of Respondents

Characteristic	Category	Frequency	Percentage
Gender	Man	185	67,27%
	Woman	90	32,73%
Age	15-16 year	95	34,55%
	17-18 year	165	60,00%
	19-20 year	15	5,45%
Class	X	90	32,73%
	XI	100	36,36%
	XII	85	30,91%

The chi-square analysis indicates that there is no significant difference in the distribution of gender ($\chi^2 = 3.24$, $p > 0.05$) and class ($\chi^2 = 1.82$, $p > 0.05$) between regions, indicating sample balance.

Digital Literacy

The results of the descriptive analysis for the digital literacy scale indicate a relatively high level of digital literacy among the respondents (M = 3.78, SD = 0.82). The item with the highest score is "I am proficient in using various software for online learning" (M = 4.12, SD = 0.76), while the item with the lowest score is "I can create simple digital content" (M = 3.45, SD = 0.98). The exploratory factor analysis identifies three main factors in digital literacy: technical skills, information literacy, and digital ethics. These factors account for 68% of the overall variance.

Table 2. Results of Digital Literacy Factor Analysis

Factor	Eigenvalue	% Variance	Related Items
Technical Skills	3.24	32.4%	LD1, LD2, LD7
Information Literacy	2.18	21.8%	LD3, LD5, LD9
Digital Ethics	1.38	13.8%	LD4, LD8, LD10

Online Learning Motivation

The online learning motivation scale revealed a moderate level of motivation. The item with the highest score was "I enjoy the flexibility of online learning," while the item with the lowest score was "I feel connected to my classmates in online learning." Multiple regression analysis showed that digital literacy and how influential people thought online learning was were strong predictors of motivation to learn online, accounting for 47% of the variation (F = 120.54, p < 0.001).

Perceptions of the Effectiveness of Online Learning

The descriptive analysis for the scale of perception of online learning effectiveness indicates a fairly positive level of perception (M = 3.67, SD = 0.88). The item with the highest score is "Online learning enhances my ability for self-directed learning" (M = 4.05, SD = 0.79). In contrast, the item with the lowest score is "I feel that online learning is as effective as face-to-face learning" (M = 3.12, SD = 1.15). The Pearson correlation analysis indicates a significant positive relationship between the perception of the effectiveness of online learning and digital literacy (r = 0.58, p < 0.001), as well as online learning motivation (r = 0.62, p < 0.001).

Comprehension of Maritime-Related Subjects

The assessment of maritime-related subject comprehension revealed a moderate level of understanding among the students. Item analysis indicated that students had a good grasp of basic maritime concepts such as stability and displacement but struggled with more complex topics like propulsion systems and navigation.

Table 3. Distribution of Shipping Material Comprehension Test Scores

Score Range	Frequency	Percentage
0-5	15	5,45%
6-10	62	22,55%
11-15	138	50,18%
16-20	60	21,82%

ANOVA results showed statistically significant differences in the levels of understanding based on grade level (F = 15.67, p < 0.001), with 12th-grade students demonstrating better comprehension than their 10th and 11th-grade counterparts. However, there were no significant differences in understanding based on gender (F = 1.24, p > 0.05).

Interrelationships Among Variables

The Pearson correlation analysis revealed significant positive relationships among all the critical research variables.

Table 4. Correlation Matrix between Variables

Variable	1	2	3	4
Digital Literacy	1			
Motivation for Online Learning	0.54**	1		
Perception of Effectiveness	0.58**	0.62**	1	
Material Understanding	0.42**	0.39**	0.45**	1

** p < 0.001

To identify the factors that influence students' comprehension of maritime-related subjects in the context of online learning, we conducted a hierarchical regression analysis. The final model explained 43% of the variance in the comprehension score (F = 40.56, p < 0.001).

Predictive Models

In order to determine the variables that influence the comprehension of shipping material in the context of online education, we carried out a hierarchical regression analysis. The ultimate model accounts for 43% of the variability in the content comprehension score ($R^2 = 0.43$, $F(5, 269) = 40.56$, $p < 0.001$).

Table 5. Results of Hierarchical Regression Analysis

Predictor	β	SE	t	p
Digital Literacy	0.24	0.05	4.80	<0.001
Motivation for Online Learning	0.18	0.06	3.00	0.003
Perception of Effectiveness	0.29	0.06	4.83	<0.001
Class (XI vs X)	0.15	0.07	2.14	0.033
Class (XII vs X)	0.22	0.07	3.14	0.002

Structural Analysis

In order to comprehend the intricate connections between variables, we employed Structural Equation Modelling (SEM). The model suggested demonstrates a strong alignment with the data, as evidenced by the statistical measures: $\chi^2 = 245.67$, df = 84, $p < 0.001$; CFI = 0.94; TLI = 0.92; RMSEA = 0.058, with a 90% confidence interval of [0.049, 0.067].

Discussion

This study provides valuable insights into the dynamics of online learning in the context of vocational maritime education at the high school level. The key findings and their implications are discussed as follows:

Digital Literacy as the Foundation for Online Learning

The study findings indicate that the respondents generally exhibited a relatively high level of digital literacy, with technical skills, information literacy, and digital ethics identified as the key underlying components. This underscores the importance of cultivating digital literacy in vocational education (Özsoy et al., 2020; Nguyen & Habók, 2022; Yeşilyurt & Vezne, 2023). However, the low score on the item "I can create simple digital content" suggests a need to enhance students' capabilities in producing digital content. Prior research, Ng (2012) has highlighted the challenges in teaching digital literacy to "digital natives." This study corroborates this notion, revealing that while vocational high school students are proficient in using online learning software, they still require support in mastering more advanced aspects of digital literacy. This suggests that assumptions about the inherent digital proficiency of younger generations may need to be re-evaluated, particularly in specialized technical fields like maritime education.

The findings of this study also bridge gaps in the literature by providing a specific understanding of the digital literacy profile of maritime vocational high school students in Indonesia. Compared to previous studies that have tended to focus on higher education or engineering in general, this research offers valuable insights into the unique digital literacy development needs in the context of maritime vocational education.

Online Learning Motivation: Challenges and Opportunities

The analysis suggests a moderate level of online learning motivation among the students, with the flexibility of online learning being the most appealing aspect. This finding aligns with prior studies by Hartnett et al. (2011), highlighting the complex nature of motivation in distance education contexts. However, the low score related to feeling connected with classmates during online learning indicates that social isolation is a potential challenge for these maritime vocational high school students. This research contributes to the literature by providing a nuanced understanding of the dynamics of online learning motivation in the specific context of maritime vocational education. Compared to earlier, more general investigations, this study reveals that students in maritime vocational high schools face unique challenges in maintaining their motivation, particularly regarding social interactions and peer-to-peer collaboration (Y.-Y. Lau et al., 2021) and (Heirs & Manuel, 2021).

The regression analysis revealed that digital literacy and perceptions of online learning effectiveness were significant predictors of students' motivation to engage in online learning. These findings expand our understanding of the interconnected relationship between digital skills, perceptions of learning modalities, and student motivation in the context of vocational online education.

Perceptions of Effectiveness and Their Relationship with Subject Comprehension

The study findings indicate that participants generally hold a relatively positive perception of the effectiveness of online learning, with the aspect of enhancing self-directed learning ability being viewed most favorably. This aligns with prior research by Netchaeva et al. (2022), suggesting the potential of online learning to promote autonomous learning among technical students. However, the relatively low rating on the perceived equivalence of online and face-to-face learning reveals some skepticism about the ability of online methods to replace traditional classroom-based instruction fully. The study findings indicate that students' perceptions of the effectiveness of online learning are significantly and positively related to their level of digital literacy and motivation to engage in online learning (Francis et al., 2019; Hart et al., 2019; Zheng et al., 2020; Paulsen & McCormick, 2020; Lai et al., 2022). This suggests that aligning online and classroom-based instructional approaches could help create a more coherent and integrated learning experience. This insight presents an opportunity to investigate further the complex interrelationships between digital competencies, learner motivation, and the perceived efficacy of online learning in the context of vocational maritime education at the high school level (Simmons & McLean, 2020; Pipchenko & Kovtunenko, 2020; Y.-Y. Lau et al., 2021; Yuen et al., 2022).

This study breaks new ground in the literature by giving us more detailed information about the factors that affect how well people learn online in the context of marriage education. Compared to the previous study, which focused more on high school education, this study shows that SMK students have a unique perspective to consider when developing an effective online learning strategy.

Understanding of Maritime Subject Matter: Successes and Challenges

The assessment of understanding of maritime subject matter indicates a moderate level of comprehension, with a firm grasp of fundamental concepts but difficulties with more complex topics. This finding aligns with prior research demonstrating the effectiveness of 3D simulations in enhancing students' mastery of specific techniques (Renganayagalu et al., 2019; Heirs & Manuel, 2021; Tusher et al., 2023). However, the results also suggest challenges in teaching advanced concepts through online platforms.

The significant difference in understanding scores by grade level ($F = 15.67$, $p < 0.001$) indicates that comprehension increases with higher levels of education. This is consistent with findings about the long-term impact of online learning on developing vocational skills (Francis et al., 2019). However, the lack of significant difference based on gender ($F = 1.24$, $p > 0.05$) challenges assumptions about gender gaps in technical understanding.

This study makes a significant contribution by giving us empirical data on how well online learning improves students' understanding of subject-related topics at the SMK level. Compared to the previous study, which focused on high school or general technical fields, this thesis gives specific information about the pros and cons of online learning in the context of marriage education.

Predictive Model and Its Implications

The hierarchical regression model developed in this study explains 43% of the variance in subject matter comprehension scores ($R^2 = 40.56$, $p < 0.001$), with digital literacy, online learning

motivation, perceptions of effectiveness, and grade level as significant predictors. This research builds upon the model proposed by Ho et al. (2021) by incorporating a specific dimension related to online learning in maritime vocational education. The relative contributions of each predictor provide valuable insights into the factors influencing the success of online learning in maritime vocational high schools. Digital literacy and perceived effectiveness emerge as the most robust predictors, underscoring the importance of fostering students' trust in these instructional methods. The excellent fit of the Structural Equation Modeling analysis further validates the proposed conceptual model, expanding our understanding of the complex interplay between various factors that affect subject matter comprehension in the online learning context of maritime vocational high schools.

Practical and Theoretical Implications

The findings of this research have significant practical implications for curriculum development and learning strategies in maritime vocational high schools. First, digital literacy as a predictor of subject matter comprehension underscores the need to systematically integrate digital skills training into the curriculum. This aligns with Beneroso Robinson's recommendations (2022) and Malyuga Petrosyan (2022) regarding integrating digital literacy in vocational education.

Second, the study findings indicate that student motivation and the ability to interact socially are crucial factors in online learning. Prior research by Netchaeva et al. (2022) has suggested using project-based learning approaches and gamification techniques as practical strategies to address these challenges. This study provides empirical evidence supporting the importance of implementing such strategies in the context of maritime vocational education.

Thirdly, the finding that perceived effectiveness is a crucial predictor of subject matter comprehension underscores the need for instructional approaches that can bolster students' confidence in online learning. Prior research has highlighted the importance of interactivity and content relevance in enhancing perceptions of effectiveness (Pei & Wu, 2019) and (Smith et al., 2021). The current study seeks to build upon this knowledge by investigating how these instructional design principles can be applied in the specific context of maritime vocational education.

From a theoretical perspective, this research contributes to developing a more comprehensive conceptual model regarding the factors that influence the success of online learning in vocational-technical education. The proposed model considers the role of digital literacy, motivation, and perceived effectiveness in maritime vocational education.

Limitations and Future Research Directions

This study provides valuable insights, but several limitations should be considered. The cross-sectional design restricts the ability to draw causal conclusions, so longitudinal research is needed to understand the long-term development of vocational skills and the effects of online learning (Zhang et al., 2024). Additionally, the focus on student perceptions and written assessments may not fully capture the complexity of practical learning in the maritime domain (Syed Abd Halim et al., 2023) and (Owolabi et al., 2024). Future research could incorporate more comprehensive evaluations of practical skills through simulation or virtual reality technologies. Furthermore, the study's limitation to the Indonesian context constrains the generalizability of the findings, underscoring the importance of cross-cultural comparisons to gain deeper insights into the factors influencing online vocational education effectiveness (Netchaeva et al., 2022). Expanding the research to explore the application of emerging technologies, like augmented reality and kinesthetic learning Yang et al. (2021) and Türkistanli (2024), as well as the role of professional educators in creating effective online learning environments Ho et al. (2021), could further contribute to enhancing the quality of online education in this field.

Conclusion

This study provides valuable insights into the factors influencing online learning success in maritime vocational high schools. The key findings indicate that digital literacy, online learning motivation, and perceptions of online learning effectiveness are critical determinants of student comprehension. The study proposes practical implications, including the need to integrate digital skills training, implement engaging instructional strategies, and foster positive perceptions of online learning to enhance the quality of maritime vocational education. The predictive model highlights the importance of developing digital skills and designing learning approaches to improve students' confidence in online learning. These insights directly affect maritime vocational high schools' curriculum development and

instructional strategies. This research develops a conceptual model integrating digital literacy, motivation, and perceptions of effectiveness in online learning for maritime vocational education. While providing valuable insights, the study has limitations in its cross-sectional design, focus on perceptions and written assessments, and Indonesia-specific context. Future research should explore longitudinal studies, practical skills assessments, cross-cultural comparisons, and emerging technologies like augmented reality and AI. Overall, this work contributes to understanding online learning dynamics in maritime vocational education, with implications for technical vocational education in the digital era.

References

Ahmad, S., Mohd Noor, A. S., Alwan, A. A., Gulzar, Y., Khan, W. Z., & Reegu, F. A. (2023). eLearning Acceptance and Adoption Challenges in Higher Education. *Sustainability*, *15*(7), 6190. https://doi.org/10.3390/su15076190

Almomani, L. M., Halalsheh, N., Al-Dreabi, H., Al-Hyari, L., & Al-Quraan, R. (2023). Self-directed learning skills and motivation during distance learning in the COVID-19 pandemic (case study: The university of Jordan). *Heliyon*, *9*(9), e20018. https://doi.org/10.1016/j.heliyon.2023.e20018

Alshammary, F. M., & Alhalafawy, W. S. (2023). Digital Platforms and the Improvement of Learning Outcomes: Evidence Extracted from Meta-Analysis. *Sustainability*, *15*(2), 1305. https://doi.org/10.3390/su15021305

Arnold, I. J. M. (2022). Online proctored assessment during COVID-19: Has cheating increased? *The Journal of Economic Education*, *53*(4), 277–295. https://doi.org/10.1080/00220485.2022.2111384

Basak, S. K. (2017). A Framework on the Factors Affecting to Implement Maritime Education and Training System in Educational Institutions: A Review of the Literature. *Procedia Engineering*, *194*, 345–350. https://doi.org/10.1016/j.proeng.2017.08.155

Beneroso, D., & Robinson, J. (2022). Online project-based learning in engineering design: Supporting the acquisition of design skills. *Education for Chemical Engineers*, *38*, 38–47. https://doi.org/10.1016/j.ece.2021.09.002

Besser, A., Flett, G. L., & Zeigler-Hill, V. (2022). Adaptability to a sudden transition to online learning during the COVID-19 pandemic: Understanding the challenges for students. *Scholarship of Teaching and Learning in Psychology*, *8*(2), 85–105. https://doi.org/10.1037/stl0000198

Chen, S. Y., & Wang, J.-H. (2021). Individual differences and personalized learning: a review and appraisal. *Universal Access in the Information Society*, *20*(4), 833–849. https://doi.org/10.1007/s10209-020-00753-4

Chen, X., Bai, X., & Xiao, Y. (2017). The Application of E-learning in Maritime Education and Training in China. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, *11*(2), 163–168. https://doi.org/10.12716/1001.11.02.19

Chen, Z., Chia, A., & Bi, X. (2021). Promoting innovative learning in training and adult education – a Singapore Story. *Studies in Continuing Education*, *43*(2), 196–207. https://doi.org/10.1080/0158037X.2020.1772224

Dalipi, F., Yayilgan, S. Y., Imran, A. S., & Kastrati, Z. (2016). Towards Understanding the MOOC Trend: Pedagogical Challenges and Business Opportunities. In *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)* (Vol. 9753, hal. 281–291). https://doi.org/10.1007/978-3-319-39483-1_26

Demir, M., Demir, Ş. Ş., & Aktürk, O. (2023a). The Effects of Distance Education Capabilities and Competencies on Learning Outcomes During COVID-19 in Higher Education Institutions. *Journal of Hospitality & Tourism Education*, 1–12. https://doi.org/10.1080/10963758.2023.2191966

Demir, M., Demir, Ş. Ş., & Aktürk, O. (2023b). The Effects of Distance Education Capabilities and Competencies on Learning Outcomes During COVID-19 in Higher Education Institutions. *Journal of Hospitality & Tourism Education*, 1–12. https://doi.org/10.1080/10963758.2023.2191966

Ebner, C., & Gegenfurtner, A. (2019). Learning and Satisfaction in Webinar, Online, and Face-to-Face Instruction: A Meta-Analysis. *Frontiers in Education*, *4*(September), 1–11. https://doi.org/10.3389/feduc.2019.00092

El-Sabagh, H. A. (2021). Adaptive e-learning environment based on learning styles and its impact on development students' engagement. *International Journal of Educational Technology in Higher Education*, *18*(1), 53. https://doi.org/10.1186/s41239-021-00289-4

Francis, M. K., Wormington, S. V., & Hulleman, C. (2019). The Costs of Online Learning: Examining Differences in Motivation and Academic Outcomes in Online and Face-to-Face Community

College Developmental Mathematics Courses. *Frontiers in Psychology*, *10*(September), 1–12. https://doi.org/10.3389/fpsyg.2019.02054

Hart, C. M. D., Berger, D., Jacob, B., Loeb, S., & Hill, M. (2019). Online Learning, Offline Outcomes: Online Course Taking and High School Student Performance. *AERA Open*, *5*(1), 233285841983285. https://doi.org/10.1177/2332858419832852

Heirs, S., & Manuel, M. E. (2021). Sustainable Maritime Career Development: A case for Maritime Education and Training (MET) at the Secondary Level. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, *15*(1), 91–99. https://doi.org/10.12716/1001.15.01.08

Hill, G., Mason, J., & Dunn, A. (2021). Contract cheating: an increasing challenge for global academic community arising from COVID-19. *Research and Practice in Technology Enhanced Learning*, *16*(1), 24. https://doi.org/10.1186/s41039-021-00166-8

Ho, N. T. T., Sivapalan, S., Pham, H. H., Nguyen, L. T. M., Pham, A. T. Van, & Dinh, H. V. (2021). Students' adoption of e-learning in emergency situation: the case of a Vietnamese university during COVID-19. *Interactive Technology and Smart Education*, *18*(2), 246–269. https://doi.org/10.1108/ITSE-08-2020-0164

Kuputri, N. M. (2020). Digital Divide: A Critical Approach to Digital Literacy in 'Making Indonesia 4.0.' *Proceedings of the 2nd Tarumanagara International Conference on the Applications of Social Sciences and Humanities (TICASH 2020)*, *478*(Ticash), 1–6. https://doi.org/10.2991/assehr.k.201209.001

Lai, J. W. M., De Nobile, J., Bower, M., & Breyer, Y. (2022). Comprehensive evaluation of the use of technology in education – validation with a cohort of global open online learners. *Education and Information Technologies*, *27*(7), 9877–9911. https://doi.org/10.1007/s10639-022-10986-w

Lancaster, T., & Cotarlan, C. (2021). Contract cheating by STEM students through a file sharing website: a Covid-19 pandemic perspective. *International Journal for Educational Integrity*, *17*(1), 3. https://doi.org/10.1007/s40979-021-00070-0

Larionova, V., Brown, K., Bystrova, T., & Sinitsyn, E. (2018). Russian perspectives of online learning technologies in higher education: An empirical study of a MOOC. *Research in Comparative and International Education*, *13*(1), 70–91. https://doi.org/10.1177/1745499918763420

Lau, Y.-Y., Dragomir, C., Tang, Y.-M., & Ng, A. K. Y. (2021). Maritime Undergraduate Students: Career Expectations and Choices. *Sustainability*, *13*(8), 4297. https://doi.org/10.3390/su13084297

Lau, Y., & Ng, A. K. Y. (2015). The motivations and expectations of students pursuing maritime education. *WMU Journal of Maritime Affairs*, *14*(2), 313–331. https://doi.org/10.1007/s13437-015-0075-3

Le, B., Lawrie, G. A., & Wang, J. T. H. (2022). Student Self-perception on Digital Literacy in STEM Blended Learning Environments. *Journal of Science Education and Technology*, *31*(3), 303–321. https://doi.org/10.1007/s10956-022-09956-1

Li, S., Zhang, C., Liu, Q., & Tong, K. (2022). E-Learning during COVID-19: perspectives and experiences of the faculty and students. *BMC Medical Education*, *22*(1), 328. https://doi.org/10.1186/s12909-022-03383-x

Liu, M., & Yu, D. (2023). Towards intelligent E-learning systems. *Education and Information Technologies*, *28*(7), 7845–7876. https://doi.org/10.1007/s10639-022-11479-6

Malyuga, E. N., & Petrosyan, G. O. (2022). Effective Integration of Distance Courses Through Project-Based Learning. *Frontiers in Education*, *6*(January), 1–9. https://doi.org/10.3389/feduc.2021.788829

Martes, L. (2020). Best Practices in Competency-based Education in Maritime and Inland Navigation. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, *14*(3), 557–562. https://doi.org/10.12716/1001.14.03.06

Mathana, S., & Galdolage, B. S. (2023). The effect of Self-Directed Learning Motives and Students' Cooperation on the success of Online Learning: The moderating effect of Resource Availability. *Journal of Business and Technology*, *7*(1), 1–24. https://doi.org/10.4038/jbt.v7i1.105

Netchaeva, E., Sheppard, L. D., & Balushkina, T. (2022). A meta-analytic review of the gender difference in leadership aspirations. *Journal of Vocational Behavior*, *137*, 103744. https://doi.org/10.1016/j.jvb.2022.103744

Ng, W. (2012). Can we teach digital natives digital literacy? *Computers & Education*, *59*(3), 1065–1078. https://doi.org/10.1016/j.compedu.2012.04.016

Nguyen, L. A. T., & Habók, A. (2022). Digital Literacy of EFL Students: An Empirical Study in Vietnamese Universities. *Libri*, *72*(1), 53–66. https://doi.org/10.1515/libri-2020-0165

Nguyen, L. A. T., & Habók, A. (2024). Tools for assessing teacher digital literacy: a review. *Journal of Computers in Education*, *11*(1), 305–346. https://doi.org/10.1007/s40692-022-00257-5

Okoye, K., Hussein, H., Arrona-Palacios, A., Quintero, H. N., Ortega, L. O. P., Sanchez, A. L., Ortiz, E. A., Escamilla, J., & Hosseini, S. (2023). Impact of digital technologies upon teaching and learning in higher education in Latin America: an outlook on the reach, barriers, and bottlenecks. *Education and Information Technologies*, *28*(2), 2291–2360. https://doi.org/10.1007/s10639-022-11214-1

Onitsuka, K., Hidayat, A. R. T., & Huang, W. (2018). Challenges for the next level of digital divide in rural Indonesian communities. *The Electronic Journal Of Information Systems In Developing Countries*, *84*(2), 1–25. https://doi.org/10.1002/isd2.12021

Owolabi, O., Abedoh, H., Abiodun, P., Ikiriko, S., Wemida, A., Duru, C., Nwachukwu, N. J., Bello, M., Emiola-Owolabi, O., Efe, S., Chavis, C., Ahangari, S., Hunter, J., Efe, F., Bhandari, A., Oguntimein, G., Shokouhian, M., James-Okeke, P., Shourabi, N. B., … Ladeji-Osias, J. (2024). Hands-on Learning Pedagogy in Teaching Concepts Relevant in the Analysis, Design, and Maintenance of Transportation Infrastructure Systems. *Transportation Research Record: Journal of the Transportation Research Board*, *May*. https://doi.org/10.1177/03611981241242067

Özsoy, D., Akbulut, E., Atılgan, S. S., & Muschert, G. W. (2020). Determinants of digital skills in Northeast Anatolia, Turkey. *Journal of Multicultural Discourses*, *15*(2), 148–164. https://doi.org/10.1080/17447143.2020.1797053

Paulsen, J., & McCormick, A. C. (2020). Reassessing Disparities in Online Learner Student Engagement in Higher Education. *Educational Researcher*, *49*(1), 20–29. https://doi.org/10.3102/0013189X19898690

Pei, L., & Wu, H. (2019). Does online learning work better than offline learning in undergraduate medical education? A systematic review and meta-analysis. *Medical Education Online*, *24*(1), 1666538. https://doi.org/10.1080/10872981.2019.1666538

Pipchenko, O., & Kovtunenko, D. (2020). A Suggestion of an Application of Blended Learning in MET Through a Harmonized STCW Model. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, *14*(3), 545–548. https://doi.org/10.12716/1001.14.03.04

Reddy, P., Sharma, B., & Chaudhary, K. (2022). Digital literacy: a review in the South Pacific. *Journal of Computing in Higher Education*, *34*(1), 83–108. https://doi.org/10.1007/s12528-021-09280-4

Rehman, Z. ur. (2023). Trends and Challenges of Technology-Enhanced Learning in Geotechnical Engineering Education. *Sustainability*, *15*(10), 7972. https://doi.org/10.3390/su15107972

Renganayagalu, S. K., Mallam, S., Nazir, S., Ernstsen, J., & Haavardtun, P. (2019). Impact of Simulation Fidelity on Student Self-efficacy and Perceived Skill Development in Maritime Training. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, *13*(3), 663–669. https://doi.org/10.12716/1001.13.03.25

Rosenberg, J. M., Schultheis, E. H., Kjelvik, M. K., Reedy, A., & Sultana, O. (2022). Big data, big changes? The technologies and sources of data used in science classrooms. *British Journal of Educational Technology*, *53*(5), 1179–1201. https://doi.org/10.1111/bjet.13245

Rundle, K., Curtis, G. J., & Clare, J. (2023). Why students do not engage in contract cheating: a closer look. *International Journal for Educational Integrity*, *19*(1), 11. https://doi.org/10.1007/s40979-023-00132-5

Shah, S., & Arinze, B. (2023). Comparing Student Learning in Face-to-Face Versus Online Sections of an Information Technology Course. *IEEE Transactions on Professional Communication*, *66*(1), 48–58. https://doi.org/10.1109/TPC.2022.3228025

Silvana, T. S., Ekohariadi, Buditjahjanto, I. G. P., Rijanto, T., Munoto, & Nurlaela, L. (2021). Study of the implementation of online learning models in vocational schools. *Journal of Physics: Conference Series*, *1810*(1), 012066. https://doi.org/10.1088/1742-6596/1810/1/012066

Simmons, E., & McLean, G. (2020). Understanding the paradigm shift in maritime education. *Worldwide Hospitality and Tourism Themes*, *12*(1), 90–97. https://doi.org/10.1108/WHATT-10-2019-0062

Smith, Y., Chen, Y.-J., & Warner-Stidham, A. (2021). Understanding online teaching effectiveness: Nursing student and faculty perspectives. *Journal of Professional Nursing*, *37*(5), 785–794. https://doi.org/10.1016/j.profnurs.2021.05.009

Syed Abd Halim, S. A., Yusoff, M. S. B., Yaman, M. N., Razali, S. A., Tengku Muda, T. F. M., Ramli, R. R., Kadir, F., & Hadie, S. N. H. (2023). Clinical students' reflections on the preclinical anatomy learning experience. *Journal of Taibah University Medical Sciences*, *18*(4), 757–770. https://doi.org/10.1016/j.jtumed.2022.12.007

Tay, L. Y., Lee, S.-S., & Ramachandran, K. (2021). Implementation of Online Home-Based Learning and Students' Engagement During the COVID-19 Pandemic: A Case Study of Singapore Mathematics Teachers. *The Asia-Pacific Education Researcher*, *30*(3), 299–310. https://doi.org/10.1007/s40299-021-00572-y

Theobald, M., & Bellhäuser, H. (2022). How am I going and where to next? Elaborated online feedback improves university students' self-regulated learning and performance. *The Internet and Higher Education*, *55*, 100872. https://doi.org/10.1016/j.iheduc.2022.100872

Türkistanli, T. T. (2024). Advanced learning methods in maritime education and training: A bibliometric analysis on the digitalization of education and modern trends. *Computer Applications in Engineering Education*, *32*(1). https://doi.org/10.1002/cae.22690

Tusher, H. M., Nazir, S., Ghosh, S., & Rusli, R. (2023). Seeking the Best Practices of Assessment in Maritime Simulator Training. *TransNav, the International Journal on Marine Navigation and Safety of Sea Transportation*, *17*(1), 105–114. https://doi.org/10.12716/1001.17.01.10

Vaskova Kjulavkovska, M., Serafini, G. O., & Szamosi, L. T. (2022). Integrating training and performance management of civil aviation inspectors: A pilot study of the mediating role of competency-based training. *International Journal of Training and Development*, *26*(1), 29–54. https://doi.org/10.1111/ijtd.12234

Wahjusaputri, S., & Nastiti, T. I. (2022). Digital literacy competency indicator for Indonesian high vocational education needs. *Journal of Education and Learning (EduLearn)*, *16*(1), 85–91. https://doi.org/10.11591/edulearn.v16i1.20390

Wang, C.-Y., Zhang, Y.-Y., & Chen, S.-C. (2021). The Empirical Study of College Students' E-Learning Effectiveness and Its Antecedents Toward the COVID-19 Epidemic Environment. *Frontiers in Psychology*, *12*(August), 1–14. https://doi.org/10.3389/fpsyg.2021.573590

Yang, J., Liu, F., Wang, J., Kou, Z., Zhu, A., & Yao, D. (2021). Effect of virtual reality technology on the teaching of urban railway vehicle engineering. *Computer Applications in Engineering Education*, *29*(5), 1163–1175. https://doi.org/10.1002/cae.22371

Yang, J., Liu, F., Zhu, A., Wang, J., Yao, D., Wang, X., & Kou, Z.-H. (2022). Effect of virtual reality guidance system on the overhaul teaching. *Computer Applications in Engineering Education*, *30*, 1060–1071.

Yeşilyurt, E., & Vezne, R. (2023). Digital literacy, technological literacy, and internet literacy as predictors of attitude toward applying computer-supported education. *Education and Information Technologies*, *28*(8), 9885–9911. https://doi.org/10.1007/s10639-022-11311-1

Yuen, K. F., Tan, L., & Loh, H. S. (2022). Core Competencies for Maritime Business Educators in the Digital Era. *Frontiers in Psychology*, *13*(July), 1–16. https://doi.org/10.3389/fpsyg.2022.915980

Zgraggen, M. (2021). Blended learning model in a vocational educational training hospitality setting: from teachers' perspectives. *International Journal of Training Research*, *19*(3), 202–228. https://doi.org/10.1080/14480220.2021.1933568

Zhang, Z., Liu, T., Gao, X. (Andy), & Lee, C. B. (2024). A longitudinal examination of language learners' group-level enjoyment and emotion regulation in online collaborative learning. *Language Teaching Research*. https://doi.org/10.1177/13621688241227584

Zheng, B., Lin, C.-H., & Kwon, J. B. (2020). The impact of learner-, instructor-, and course-level factors on online learning. *Computers & Education*, *150*(January), 103851. https://doi.org/10.1016/j.compedu.2020.103851