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Shipboard Automation and Digitalization: Their Relevance to Maritime Education and Training

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Abstract
This descriptive–correlational study aimed to determine the relevance of shipboard automation and digitalization to Maritime Education and Training (MET) and to examine the relationship between these technological advancements within maritime instruction and professional practice. The study sought to provide empirical evidence on how automation and digital systems influence the preparation of maritime professionals for modern shipboard operations. The respondents of the study consisted of maritime technical instructors, industry stakeholders, and active seafarers. They were purposively selected based on their direct involvement in MET and shipboard operations, ensuring that the data collected were informed by practical experience and professional expertise. A researcher-constructed questionnaire was used to gather data on the perceived relevance of shipboard automation and digitalization in MET. The collected data were analyzed using appropriate statistical tools, including the mean and standard deviation for descriptive analysis, the Mann–Whitney U test and Kruskal–Wallis test for differences across groups, and Spearman's rho correlation coefficient to determine relationships among variables. All statistical tests were conducted at the 0.05 level of significance. The findings revealed that shipboard automation and digitalization are highly relevant to MET. Furthermore, no significant differences were found in the perceptions of respondents when grouped according to selected profiles. Additionally, a significant relationship was observed between automation and digitalization, indicating that these two technological domains are closely interconnected and mutually reinforcing in maritime operations and education. Based on the results, the study recommends continual development training for active seafarers for effective use of automation and digital technologies onboard.

Keywords: Shipboard Automation, Digitalization, Maritime Education and Training (MET), Maritime Professionals, Technological Integration

Introduction

Automation and digitalization are rapidly becoming part of the shipping fabric, altering the way vessels operate. Yet, Maritime Education and Training (MET) is still primarily bound by traditional teaching methods. While the existing literature exhaustively chronicles the benefits of "smart" shipping for operational efficiency, there is a crucial study void on the pedagogic reforms essential to train future seafarers for these high-tech environments. This research bridges that gap by experimentally evaluating the significance of these technologies from the viewpoints of seafarers, instructors and industry stakeholders. This research develops a new framework to explore the perception and adoption of modern digital skills by maritime professionals by integrating the Technology Acceptance Model (TAM) and the Diffusion of Innovation (DOI) theory. Unlike previous studies that focused on technical safety or efficiency, this study directly supports educational curriculum design. This study provides a data-driven path to align MET with the changing demands of 21st Century maritime landscape. The results described critical information for policy makers and educators faced with the challenge of bridging the expanding gap between the classroom and the realities of automated marine operations.

Materials and Methods

According to the International Maritime Organization (IMO, 2018) [4], automation improves navigational safety, reduces human error, and enhances operational efficiency, increasing the demand for highly skilled seafarers. Digitalization refers to the use of digital technologies to enhance maritime operations, communication, and decision-making. Systems such as

Electronic Chart Display and Information Systems (ECDIS), real-time vessel tracking, and predictive maintenance tools have become essential in modern shipping. Jansen *et al.* (2020) [6] noted that digitalization improves efficiency and safety, requiring maritime training programs to develop digital literacy and technological competence among students. However, Japitana (2025) [7] highlighted other challenges that focus more on the cognitive load associated with unfamiliar jargon impeded conceptual clarity and practical application, especially in regulatory and technical modules. The rapid advancement of maritime technology necessitates reforms in MET. Traditional teaching methods are no longer sufficient to prepare students for smart ships and automated port systems. The Standards of Training, Certification, and Watchkeeping for Seafarers (STCW, 1978 as amended) [10] require maritime institutions to integrate updated competencies into their curricula. Training must now include simulators, digital tools, and system-based learning to ensure graduates are industry-ready.

A total of 140 respondents from the National Capital Region were purposively selected for this study. In terms of role, 55 (39%) were maritime technical instructors, 26 (19%) were industry stakeholders, and 59 (42%) were active seafarers. As to age, 40 (29%) were 35 years old and below, while 100 (71%) were 36 years old and above. Regarding years of experience in the maritime industry, 37 (26%) had 1–10 years, 58 (41%) had 11–20 years, and 45 (33%) had 21 years and above. In terms of educational attainment, 105 (75%) held bachelor's degrees, while 35 (25%) had postgraduate studies.

Table 1: Distribution of Respondents

Category	Frequency	%
Entire Group	140	100
Role		
Maritime Technical Instructor	55	39
Industry Stakeholders	26	19
Active Seafarers	59	42
Age		
35 years old and below	40	29
36 years old and above	100	71
Years of Experience		
1–10 years	37	26
11–20 years	58	41
21 years and above	45	33
Educational Attainment		
Bachelor's Degree	105	75
Postgraduate	35	25

Data for this study were obtained using a researcher-constructed questionnaire based on indicators of shipboard automation and digitalization. The instrument consisted of 40 items, with 20 items for automation (covering deck and engine operations) and 20 items for digitalization.

Responses were measured using a five-point Likert scale: Strongly Agree (5), Agree (4), Moderately Agree (3), Disagree (2), and Strongly Disagree (1). The instrument yielded a Cronbach's alpha of 0.88, indicating good reliability for research purposes. As noted by Frankel and Wallen (2013) [1], a reliability coefficient of 0.70 or higher is acceptable.

The following scale of means was used to interpret the level of relevance of automation and digitalization in Maritime Education and Training (MET):

- 4.21–5.00: Highly Relevant – very important to MET
- 3.41–4.20: Relevant – important to MET
- 2.61–3.40: Moderately Relevant – of average importance to MET
- 1.81–2.60: Slightly Relevant – of little importance to MET
- 1.00–1.80: Not Relevant – of no importance to MET

The questionnaire was distributed through Google Forms based on the accessibility and preference of respondents. Data gathered were tallied, organized, and analyzed using appropriate descriptive and inferential statistical tools with the aid of the Statistical Package for the Social Sciences (SPSS).

This study adhered to ethical research principles. Participation was voluntary, and respondents were given a brief orientation before answering the questionnaire. Informed consent was secured at the beginning of the survey. Only respondents who met the required age and cognitive capacity were included.

The confidentiality of all respondents and their data was strictly maintained. Participants were informed that they could withdraw from the study at any time without penalty. Proper acknowledgment of all sources and authors was observed throughout the research process.

Descriptive Statistics

- Mean – Used to determine the level of relevance of automation and digitalization.
- Standard Deviation – Used to determine the variability of respondents' perceptions.

Inferential Statistics

- Mann–Whitney U Test – Used to determine significant differences between two groups.
- Kruskal–Wallis Test – Used to determine significant differences among three or more groups.
- Spearman's rho – Used to determine the relationship between automation and digitalization.

Results

The results of the study are based on the collected data. It is divided into two main parts: (1) Descriptive Data Analysis and (2) Inferential Data Analysis. The Descriptive Data Analysis presents the level of relevance of shipboard automation and digitalization in Maritime Education and Training (MET) as perceived by the respondents. The Inferential Data Analysis presents the significant differences in the relevance of automation and digitalization when grouped according to demographic profile variables, as well as the relationship between the two variables.

Part I: Descriptive Data Analysis

This section presents the findings on the relevance of shipboard automation and digitalization in Maritime Education and Training (MET) based on respondents' perceptions. The mean and standard deviation were used for analysis.

Relevance of Automation in Maritime Education and Training

As shown in Table 2, automation in Maritime Education and Training was rated as Highly Relevant by the respondents as an entire group (M = 4.29, SD = 0.497), regardless of role,

age, years of experience, and educational attainment.

In terms of role, active seafarers obtained the highest mean (M = 4.32, SD = 0.455), followed by industry stakeholders (M = 4.28, SD = 0.437) and maritime technical instructors (M = 4.27, SD = 0.570). All groups interpreted automation as Highly Relevant.

As to age, respondents aged 35 years and below (M = 4.33, SD = 0.431) had slightly higher perceptions than those aged 36 years and above (M = 4.28, SD = 0.523), yet both were interpreted as Highly Relevant.

Regarding years of experience, respondents with 1–10 years (M = 4.31, SD = 0.562) and 11–20 years (M = 4.31, SD = 0.471) showed identical means, while those with 21 years and above (M = 4.26, SD = 0.483) obtained a slightly lower mean. Nevertheless, all were rated as Highly Relevant.

In terms of educational attainment, bachelor's degree holders (M = 4.31, SD = 0.466) had slightly higher perception than postgraduate respondents (M = 4.23, SD = 0.535), both interpreted as Highly Relevant.

Overall, these findings indicate that automation is highly relevant to MET, supporting the International Maritime Organization (IMO, 2018) [4], which emphasizes its role in improving safety, reducing human error, and enhancing operational efficiency.

Table 2: Relevance of Automation in Maritime Education and Training

Category	Mean	SD	Description
Maritime Technical Instructor	4.27	0.570	Highly Relevant
Industry Stakeholders	4.28	0.437	Highly Relevant
Active Seafarers	4.32	0.455	Highly Relevant
35 years old and below	4.33	0.431	Highly Relevant
36 years old and above	4.28	0.523	Highly Relevant
1–10 years of experience	4.31	0.562	Highly Relevant
11–20 years of experience	4.31	0.471	Highly Relevant
21 years and above	4.26	0.483	Highly Relevant
Bachelor's Degree	4.31	0.466	Highly Relevant
Postgraduate Degree	4.23	0.535	Highly Relevant
Entire Group	4.29	0.497	Highly Relevant

Relevance of Digitalization in Maritime Education and Training

As shown in Table 3, digitalization in Maritime Education and Training was also rated as Highly Relevant by the respondents as an entire group (M = 4.32, SD = 0.512) across all categories.

In terms of role, maritime technical instructors obtained the highest mean (M = 4.33, SD = 0.536), followed by active seafarers (M = 4.32, SD = 0.503) and industry stakeholders (M = 4.26, SD = 0.494). All were interpreted as Highly Relevant.

As to age, respondents aged 35 years and below (M = 4.35, SD = 0.497) had slightly higher perception than those aged 36 years and above (M = 4.30, SD = 0.520), both interpreted as Highly Relevant.

Regarding years of experience, respondents with 11–20 years (M = 4.33, SD = 0.507) showed the highest mean, followed by those with 1–10 years (M = 4.31, SD = 0.552) and 21 years and above (M = 4.31, SD = 0.495).

In terms of educational attainment, bachelor's degree holders (M = 4.32, SD = 0.509) slightly outscored postgraduate respondents (M = 4.30, SD = 0.528).

These results indicate that respondents recognize the importance of digitalization in enhancing maritime operations through improved communication, data processing, and decision-making, consistent with Jansen *et al*. (2020) [6].

Table 3: Relevance of Digitalization in Maritime Education and Training

Category	Mean	SD	Description
Maritime Technical Instructor	4.33	0.536	Highly Relevant
Industry Stakeholders	4.26	0.494	Highly Relevant
Active Seafarers	4.32	0.503	Highly Relevant
35 years old and below	4.35	0.497	Highly Relevant
36 years old and above	4.30	0.520	Highly Relevant
1–10 years of experience	4.31	0.552	Highly Relevant
11–20 years of experience	4.33	0.507	Highly Relevant
21 years and above	4.31	0.495	Highly Relevant
Bachelor's Degree	4.32	0.509	Highly Relevant
Postgraduate Degree	4.30	0.528	Highly Relevant
Entire Group	4.32	0.512	Highly Relevant

Part II: Inferential Data Analysis

This section presents the results of the inferential analysis on the significant differences in the relevance of automation and digitalization when grouped according to demographic profile variables, as well as the relationship between the two variables. The Mann–Whitney U test, Kruskal–Wallis test, and Spearman's rho were used at a 0.05 level of significance.

Difference in Automation (Age and Educational Attainment)

The results revealed no significant difference in the perceived relevance of automation when grouped according to age (Z = 0.453, p = 0.650) and educational attainment (Z = 0.311, p = 0.756). Since all p-values are greater than 0.05, the null hypothesis is accepted. This indicates that respondents share similar perceptions of automation regardless of age and educational background.

Difference in Automation (Role and Years of Experience)

The Kruskal–Wallis test showed no significant differences in automation when grouped according to role ($\chi^2 = 0.555$, df = 2, p = 0.758) and years of experience ($\chi^2 = 0.932$, df = 2, p = 0.622). This implies that perceptions of automation are consistent across different professional groups.

Difference in Digitalization (Age and Educational Attainment)

No significant difference was found in the relevance of digitalization when grouped according to age (Z = 0.485, p = 0.628) and educational attainment (Z = 0.225, p = 0.822). This suggests uniform perceptions among respondents.

Difference in Digitalization (Role and Years of Experience)

The results showed no significant differences in digitalization when grouped according to role ($\chi^2 = 0.481$, df = 2, p = 0.786) and years of experience ($\chi^2 = 0.932$, df = 2, p = 0.628). This indicates similar perceptions across all groups.

Relationship Between Automation and Digitalization

The Spearman's rho correlation revealed a strong positive significant relationship between automation and

digitalization (r = 0.815, p = 0.000). This indicates that higher perceptions of automation are associated with higher perceptions of digitalization. This finding aligns with Horvat *et al*. (2019) [2], who emphasized that advancements in automation are closely linked with digitalization in modern maritime operations.

Table 4: Relationship Between Automation and Digitalization

Variables	r	Sig.
Automation & Digitalization	0.815	0.000

p < 0.05

Discussion

The findings of this study highlight the strong relevance of shipboard automation and digitalization in Maritime Education and Training (MET) as perceived by maritime technical instructors, industry stakeholders, and active seafarers. Overall, both variables were consistently rated as highly relevant, indicating strong recognition of their importance in modern maritime practice and education.

Relevance of Automation in MET

Automation was rated as highly relevant, with an overall mean of 4.29. This indicates that respondents widely acknowledge the importance of automated systems in contemporary maritime operations and training. Consistent ratings across all groups suggest a shared understanding of its significance regardless of role, age, experience, or educational background. This finding reflects the increasing reliance on automated systems such as integrated bridge systems, automated engine monitoring, and advanced navigation technologies. It supports the International Maritime Organization (IMO, 2018) [4], which emphasizes that automation improves operational efficiency, enhances safety, and reduces human error. In the context of MET, this underscores the need to continuously integrate automation-related competencies into training programs to prepare future seafarers for modern shipboard environments.

Relevance of Digitalization in MET

Digitalization also obtained a highly relevant rating, with an overall mean of 4.32. This suggests that respondents recognize the importance of digital technologies in improving communication, data management, and decision-making processes in maritime operations. The result indicates awareness of tools such as Electronic Chart Display and Information Systems (ECDIS), real-time tracking systems, and predictive maintenance technologies. This supports the findings of Jansen *et al*. (2020) [6], who noted that digitalization enhances efficiency and safety in maritime operations. In MET, this emphasizes the need to strengthen digital literacy and technological competence among maritime students and professionals.

Differences in Perceptions Across Groups

The inferential results revealed no significant differences in perceptions of both automation and digitalization when grouped according to role, age, years of experience, and educational attainment. This indicates that respondents share similar views regardless of demographic characteristics. This consistency suggests that exposure to maritime technologies is widespread across all professional categories. It further implies that automation and digitalization are now standard components of maritime practice, leading to a common understanding of their importance among instructors, stakeholders, and seafarers.

Relationship Between Automation and Digitalization

The study revealed a strong and significant positive relationship between automation and digitalization (r = 0.815, p < 0.05). This indicates that higher perceptions of automation are associated with higher perceptions of digitalization. This finding confirms that both concepts are closely interconnected and mutually reinforcing within maritime operations. Automation systems often depend on digital technologies for functionality, making their integration essential in modern shipping environments. This result aligns with Horvat *et al*. (2019) [2], who emphasized that advancements in automation are largely driven by digitalization.

Theoretical Implications

The findings support the Technology Acceptance Model (TAM), Marikyan, D. & Papagiannidis, S. (2026) [8], particularly the concept of perceived usefulness, as respondents consistently viewed both automation and digitalization as valuable in enhancing maritime training and operations. Likewise, the Diffusion of Innovation (DOI) Theory (Rogers, 2003) [9] is reflected in the uniform acceptance of these technologies across groups, suggesting that automation and digitalization have already been widely adopted within the maritime sector, with minimal variation in acceptance levels.

Conclusion

In view of the findings, the following inferences were drawn:

1. In general and when categorized as to roles, age, years of experience, and educational attainment, the usefulness of shipboard automation and digitalization is “highly relevant". The result seems to indicate that the respondents have come to realize that automation and digitalization are important in maritime education and training.
2. The significant difference in usefulness of automation when respondents were categorized as to role, age, years of experience, and educational attainment seems to indicate that the importance and necessity of automation as perceived by the respondents are similar.
3. The significant difference of usefulness of digitalization when respondents were categorized as to role, age, years of experience, and educational attainment appears to demonstrate a notable uniformity across marine professionals on the efficacy of automation in maritime education and training. Moreover, it underscores a collective recognition of the necessity to include automation into maritime curricula and training practices.
4. A positive significant relationship existed between automation and digitalization in terms of their usefulness. It could be inferred that automation is of the same importance and usefulness as digitalization, which means that they are associated with each other.

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Conflict of Interests

The study upheld ethical standards by ensuring voluntary participation, preceded by a brief orientation and informed consent embedded within the survey instrument. Respondents were required to meet age and cognitive criteria for valid engagement. Confidentiality of participant identities and related documents was strictly maintained throughout the research process. Participants retained the right to withdraw at any stage without consequence. Proper attribution of referenced scholarly works was observed, reinforcing academic integrity and ethical compliance in reporting.

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