

## Exploring Maritime Students' Readiness on Digitalized Navigational Bridge

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### ABSTRACT

This phenomenological study explores maritime cadets' first experience operating a digital navigation bridge during shipboard training. Interviews and reflection journals reveal that, despite prior simulator practice, many struggle to apply their knowledge due to limited exposure to advanced digital equipment. Cadets must quickly adapt to complex systems, high performance demands, and the vessel's fast tempo, relying on senior mentorship, observation, and hands-on practice to cope. Findings underscore the need for more immersive simulations and updated instructional tools to better prepare cadets for modern maritime operations, and call for future research on how sustained digital exposure shapes their professional readiness.

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## INTRODUCTION

The maritime industry has undergone a significant transformation with the rapid advancement of technology, particularly in navigation. Traditional navigation methods are increasingly being supplemented – or even replaced – by sophisticated digital systems that enhance operational efficiency, safety, and sustainability. Modern vessels now rely on integrated bridge systems, such as Electronic Chart Display and Information Systems (ECDIS) and Automatic Identification Systems (AIS), along with other cutting-edge navigational tools.

According to the study of Rita Margaretha et al. (2024), digital transformation in the maritime sector, driven by technologies like the Internet of Things (IoT), artificial intelligence (AI), and blockchain, has significantly improved ship operations by enabling real-time monitoring, predictive maintenance, and enhanced decision-making. These advancements have made digital systems indispensable for modern seafaring operations, as also supported by Filippopoulos et al. (2022) and Albert (2024), who emphasize that such technologies contribute to improved navigational accuracy and operational efficiency.

While these innovations enhance maritime operations, they also introduce challenges that require seafarers to develop new technical skills and digital literacy. As noted in the research of Autsadee et al. (2023) and Popoola et al. (2024), many maritime professionals struggle with the transition to digitalized navigation systems, highlighting the need for updated training programs. In response to these challenges, maritime education must evolve to meet the growing demands of the industry. The accelerating pace of technological advancement suggests that continuous updates to training curricula are necessary to equip maritime students with the skills required for modern bridge systems.

The STCW Convention and Code, as amended, serves as the international benchmark for seafarer training and education. However, as stated by The Nautical Institute (2022), the 2010 Manila Amendments aimed to update training standards, yet technological advancements in maritime operations continue to outpace these regulations. This rapid evolution underscores the need for cadets and aspiring maritime professionals to adapt quickly. Research conducted by Magsino et al. (2023) suggests that many maritime students face difficulties adjusting to modern bridge technologies, further emphasizing the gap between traditional training and current industry demands.

Furthermore, studies such as Fahmi Umasangadji et al. (2024) indicate that cadets often experience technical challenges and work-related stress during shipboard training, highlighting the need for enhanced training programs that integrate problem-solving skills, hands-on experience, and adaptability to new technologies. As the maritime industry increasingly adopts IoT-enabled navigation systems, the sector is shifting towards a more interconnected and intelligent operational framework. According to Plaza-Hernández et al. (2020), this shift has created a growing demand for technical specialists who can support the expanding smart maritime industry.

To ensure that future seafarers remain competitive, maritime institutions must bridge the gap between traditional education and the evolving digital landscape. As noted in the study of Baldevarona et al. (2024), understanding the readiness of maritime students for digitalized bridge systems is crucial in developing effective training programs that align with industry needs.

Building on these existing studies, this research explores how prepared maritime students are for a digitalized navigational bridge in the face of rapid technological advancements. Additionally, it seeks to examine their firsthand experiences, the challenges they encounter, and how they adapt during their initial shipboard training.

### ***Objective of the Study***

This study aims to explore the readiness of maritime students for a digitalized navigational bridge. Additionally, it seeks to examine their experiences, challenges, and adaptation strategies in using advanced bridge equipment.

Specifically, this study aims to answer the following questions:

1. Experiences: What are the experiences of maritime students with a digitalized navigational bridge?
2. Challenges: What challenges do they encounter while using advanced bridge equipment during their cadetship?
3. Adaptation: How do they adapt to the challenges they face?

## **THEORETICAL REVIEW**

### ***Human-Technology Interaction in the Digital Bridge***

The shift from analog to integrated-digital bridges heightens the cognitive and perceptual load on novice watch-keepers. Danielsen et al. (2021) argue that persistent “unresolved” issues in maritime human-technology interaction—ranging from information overload to sub-optimal interface design—demand higher-order situation-awareness and decision-making skills. These requirements align with Demirel’s (2020) description of a “digital era MET profile,” where cadets must blend technical, procedural and socio-technical competencies to operate safely.

### ***Simulator-Based Training and Authentic Assessment***

Kim et al. (2021) map a continuum from desktop simulators to full-mission and on-board learning, emphasising “transfer fidelity” as the pivotal factor. Sellberg & Lundin (2018) and Sellberg et al. (2018) show that instructor scaffolding and timely assessment feedback in simulations accelerate the formation of professional judgement. Authentic assessment—tasks that replicate bridge watch complexity—correlates positively with industry-readiness when instructors possess high pedagogical and operational competence (Baldevarona et al., 2024).

### ***Mentorship, Collaborative Learning, and Communities of Practice***

Mentorship bridges the “knowing-doing” gap onboard. Conrad & Wardrop (2024) and Kato et al. (2021) demonstrate that structured mentoring

relationships support reflective practice and confidence building. Paul & Kundu (2021) add that collaborative learning—peer-to-peer problem solving around complex tasks—cultivates shared mental models crucial for integrated bridge teamwork.

### ***Curriculum Modernisation: Sustainability, Law, and Policy Perspectives***

Cahyadi et al. (2024) note that sustainability imperatives and emerging digital regulations (e.g., data governance, cyber-security) are reshaping curricular content. Popoola et al. (2024) further warn that automation alters workforce structures, necessitating adaptive competence. Integrating these dimensions ensures cadets can navigate both the technical system and its regulatory-ethical context—an often-overlooked facet of readiness.

## **METHODOLOGY**

This study employs a qualitative research design using a phenomenological approach to explore the lived experiences of maritime students adapting to digitalized navigational bridge systems. According to Creswell and Poth (2018), phenomenology is a valuable approach in qualitative research as it seeks to understand individuals' personal experiences and perceptions. Given that this study focuses on how maritime students engage with modern bridge technology, a phenomenological approach provides an in-depth exploration of their experiences, challenges, and adaptation strategies in a rapidly evolving maritime industry.

The researcher had a total of five maritime cadets selected through purposive sampling to ensure they had firsthand experience with digitalized navigational bridge systems. According to Palinkas et al. (2015), purposive sampling is an effective method for selecting participants who possess relevant knowledge and insights related to the study's focus.

The number of participants was determined based on data saturation, wherein no new themes or insights emerged from additional interviews conducted. Each participant had either completed or was currently undergoing cadetship aboard vessels equipped with advanced bridge technologies, making them well-suited to provide valuable perspectives on their preparedness for digitalized navigation systems.

Data were gathered through semi-structured interviews, allowing participants to share their experiences, challenges, and adaptation strategies in depth. To ensure flexibility and convenience, interviews were conducted via Google Forms instead of traditional face-to-face or video call interviews. As highlighted by Janghorban, Roudsari, and Taghipour (2014), online methods of qualitative data collection—such as digital surveys and forms—serve as effective alternatives when direct interactions are not feasible.

Participants were presented with open-ended questions, carefully designed to encourage detailed and thoughtful responses (Patton, 2015). The use of Google Forms provided a structured yet adaptable format, enabling cadets to reflect on their experiences without time pressure.

This study strictly adheres to ethical research guidelines to ensure the rights, dignity, and well-being of all participants. Participants were fully

informed about the study's purpose, their voluntary participation, and their right to withdraw at any time without consequences.

To protect participants' privacy, their identities were anonymized, and all collected data were securely stored to prevent unauthorized access. This study ensures compliance with established ethical standards, safeguarding participants while maintaining academic integrity.

By employing a rigorous qualitative approach, structured data analysis, and ethical safeguards, this study provides an accurate and meaningful exploration of maritime students' readiness for digitalized bridge systems.

## RESULTS AND DISCUSSION

This chapter explores the experiences of maritime students as they navigated a digitalized bridge for the first time at sea as cadets. They shared the challenges they encountered, the adjustments they had to make, and how their academic learning shaped their approach to real-world maritime operations. As technology continues to evolve, their experiences highlight the growing need for seafarers to be adaptable, quick learners, and proficient in modern navigational systems. Their stories offer valuable insight into the transition from classroom education to hands-on experience, emphasizing the importance of bridging the gap between traditional training and the ever-changing demands of the maritime industry.

### *Cadets' Experiences*

Certain themes emerged in this study based on the insights and data gathered from cadets about their experiences as they embarked on their journey, transitioning from simulator-based and classroom learning to operating on an actual ship's bridge. Their firsthand accounts reveal the challenges, adjustments, and learning curves they faced in adapting to real-world maritime operations. Below is a list of cadets' key experiences when asked, "What are your experiences with the digitalized navigational bridge?"

Table 1. Cadets' Experiences

Themes	Sub-themes	Codes
Bridging Academic Learning and Practise	Academic Preparation	Knowledge retention
Enhanced Situational Awareness	Equipment Functionality	Real-time ship information

Professional Growth and Skill Development	Onboard Experience	Practical experience benefits
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**Theme 1. Bridging Academic Learning and Practice**

One of the key themes that emerged from the study is the transition from theoretical knowledge gained in the classroom to its practical application on board a vessel. Maritime education provides cadets with a strong foundation in navigation, safety protocols, and ship operations. Simulator-based training plays a crucial role in bridging academic learning and practice, allowing instructors to monitor, assess, and provide feedback to students (Sellberg, 2018; Sellberg et al., 2018).

*“...Academic fundamentals proved useful in understanding bridge equipment.” (P1)*

Cadets shared that while simulators and classroom lessons introduced them to digitalized bridge systems, operating them on an actual ship was more complex due to real-time decision-making, environmental factors, and the pressures of working alongside experienced crew members. They had to quickly adapt to new challenges, such as understanding vessel-specific equipment, responding to unforeseen situations, and applying critical thinking in dynamic maritime environments.

This theme highlights the importance between academic learning and practical training. It emphasizes the need for immersive learning experiences, such as onboard familiarization, mentorship from senior officers, and simulator training that closely mirrors real-life conditions. By strengthening this connection, cadets can transition more smoothly from theoretical knowledge to competent, hands-on practice in the maritime industry.

**Theme 2: Enhanced Situational Awareness**

Recent research highlights the importance of enhanced situational awareness in digitalized navigational bridges. Augmented reality-based decision support systems can assist bridge operators in challenging navigation conditions, improving safety at sea (Martelli et al., 2018) One of the biggest lessons cadets learned during their first shipboard experience with a digitalized navigational bridge was the importance of staying aware of everything happening around them—both inside the bridge and out at sea. While they had been taught about situational awareness in the classroom, experiencing it firsthand in a real-world setting was a whole new challenge.

*“...Digital navigational bridge equipment provides real-time ship information.”(P2)*

Unlike in a controlled simulator environment, being on an actual vessel meant they had to constantly monitor multiple factors at once—navigational equipment, electronic charts, weather conditions, and nearby vessels—all while

keeping up with the fast-paced nature of a working ship. Many realized that even a brief lapse in attention could lead to serious consequences, making them more mindful of their surroundings and responsibilities.

Through this experience, cadets became more alert, more confident in their decision-making, and more aware of how their actions impact the safety and efficiency of the vessel. They also saw how teamwork and clear communication with senior officers and crewmates played a huge role in maintaining a safe bridge watch.

This theme highlights how real-life exposure at sea helps cadets sharpen their instincts, teaching them to think quickly, anticipate risks, and stay focused even during long shifts. It reinforces the need for hands-on training that not only builds technical skills but also prepares future seafarers for the demands of modern maritime operations.

### *Theme 3. Professional Growth and Skill Development*

The digitalization of ship bridges has introduced new challenges in human-technology interaction, requiring seafarers to adapt their seamanship skills to manage complex systems (Danielsen et al., 2021). The increasing automation in the maritime industry necessitates evolving competencies for future seafarers, emphasizing the need for a better understanding of system safety in complex sociotechnical environments (MacKinnon et al., 2023). Simulator-based maritime education and training (MET) plays a crucial role in developing these competencies, with technological advancements leading to the adoption of virtual reality and cloud-based simulators (Kim et al., 2021). These developments in maritime training aim to improve professional growth and skill development for seafarers, addressing the challenges posed by digitalized navigational bridges and contributing to the fulfillment of UN Sustainable Development Goal 4 in the maritime sector (Kim et al., 2021).

*"...Onboard experiences with digital bridge technology are fresh and beneficial."  
(P3)*

Cadets Stepping onto a digitalized navigational bridge for the first time was both exciting and overwhelming. While they had studied modern navigation systems in the classroom and practiced on simulators, nothing fully prepared them for the real-world complexity of operating these systems at sea. The experience pushed them to apply their knowledge in a fast-paced, high-stakes environment, where quick thinking, precision, and adaptability were crucial.

Cadets found that onboard experiences with digital bridge technology were fresh and beneficial, giving them hands-on exposure to advanced systems like Electronic Chart Display and Information Systems (ECDIS), Automatic Identification Systems (AIS), and Integrated Bridge Systems (IBS). These tools made navigation more efficient and enhanced situational awareness, but they also demanded a higher level of focus and technical skill. Unlike in a simulator, where conditions could be controlled, working on an actual vessel meant dealing with real-time challenges—such as interpreting constantly changing data, responding to navigational hazards, and coordinating with officers during critical situations.

Beyond learning how to operate the technology, cadets also experienced personal and professional growth. They developed essential soft skills like teamwork, communication, and problem-solving, realizing that a well-functioning bridge relies just as much on human coordination as on digital tools. The experience also built their confidence, teaching them to stay composed under pressure and trust their training when making important decisions.

***Cadets’ Challenges***

The research revealed several key themes related to the complexities of operating a digitalized navigational bridge, highlighting the challenges cadets encountered during their shipboard experience. While their academic training provided a foundation based on the current curriculum, transitioning from simulators to real-world operations proved to be a significant adjustment. Three main challenges were determined from the results of their responses when asked, "What challenges do you encounter while using advanced bridge equipment during your cadetship?".

Table 2. Challenges Cadets’ Encountered

<b>Themes</b>	<b>Sub-themes</b>	<b>Codes</b>
Gaps in Technological Preparedness	Lack of exposure to advanced systems	Complicated system features
Training-Practice Disparity	Simulator-practice mismatch	System differences onboard
Curriculum and Training Gaps	Outdated Curriculum	Exposure limited to basics

***Theme 1. Gaps in Technological Preparedness***

As the maritime industry continues to embrace digitalization, cadets stepping onto a modern navigational bridge for the first time often experience a significant gap between their academic training and the advanced technologies used onboard. While simulators provide foundational knowledge, they cannot fully replicate the complexity of real-time maritime operations, leaving cadets struggling to adapt to the sophisticated systems that power today’s ships.

*“...The challenges are complicated features of some digital bridge systems and new technologies/innovations were not in school.” (P1)*

The digitalization of maritime operations presents both opportunities and challenges for the industry and education sector. While emerging technologies like AI, IoT, and blockchain enhance operational efficiency and decision-making (Winarno et al., 2024). The integration of advanced technologies in maritime education lags behind industry developments, creating a disconnect between theoretical knowledge and practical application (Mohamed & Elnoury, 2023). Seafarers face ongoing challenges with human-technology interaction on digitalized ship bridges, requiring them to adapt and apply seamanship skills to manage new systems effectively (Danielsen et al., 2021). The rapid evolution of maritime technology means that navigation software, system interfaces, and digital tools often advance faster than educational institutions can update their curriculum. As a result, some cadets encountered new system versions and unfamiliar functions onboard, making it difficult to operate efficiently without guidance from experienced officers. To address these issues, there is a pressing need for educational reform, continuous professional development, and improved alignment between maritime education and industry requirements (Winarno et al., 2024; Mohamed & Elnoury, 2023).

This gap in technological preparedness underscores the need for continuous learning and industry-aligned training. Mohamed & Elnoury (2023) emphasize the importance of developing maritime education to bridge the gap between technological progress and the readiness of maritime institutes. They suggest incorporating AI and Virtual Reality techniques in education and training to enhance students' capabilities. Collaboration between industry and educational institutions is crucial to address these challenges and ensure graduates are adequately prepared for the digital era in maritime operations. More so, Maritime education must evolve to incorporate more hands-on experience with the latest bridge technologies, ensuring that cadets are not only familiar with digital navigation but also proficient in operating, troubleshooting, and adapting to advanced systems in real-world conditions.

### ***Theme 2. Training-Practice Disparity***

Effective simulator training requires a focus on tasks rather than specific skills, with instructors guiding students towards maritime work practices (Sellberg & Lundin, 2018). While maritime education provides theoretical knowledge and simulator-based exercises, the technological gap between training facilities and modern vessels has widened this disparity. Many cadets found themselves facing updated versions of ECDIS, IBS, and other digital bridge systems that differed significantly from those they had trained on in school. This forced them to learn on the job, often relying on senior officers to guide them through system interfaces and advanced functionalities they had never seen before.

*"...How to use the system, since the systems onboard are different from the ones we use in the simulators in school and some systems we don't have hands-on experience with."(P4)*

To address the training-practice disparity in digitalized navigation, closer collaboration between industry and education institutions is necessary, along with the integration of IT technology in teaching methods (Demirel, 2020;

MacKinnon et al., 2023). The maritime workforce requires upskilling to effectively handle new digital tools, necessitating substantial investment in education and training (Rita Margaretha et al., 2024)

This training-practice disparity highlights the need for maritime education to continuously update its curriculum, integrate real-world case studies, and enhance simulator training with more complex, real-time scenarios. Bridging this gap will help cadets gain greater confidence and competence in handling digital bridge operations, ensuring they are better prepared to meet the evolving demands of the maritime industry.

### ***Theme 3. Curriculum and Training Gaps***

As technology continues to reshape the maritime industry, cadets have found that their training doesn't always keep pace with the advanced systems they encounter at sea. While their academic courses and simulator sessions provide a solid foundation, the transition to real-world digital bridge operations often reveals gaps in their preparation.

The Global Maritime Professional Body of Knowledge (GMP-BoK) addresses the gap between industry expectations and MET programs, offering a framework for curriculum development and gap analysis (Ghalwash et al., 2022). While the STCW convention standardizes seafarer education, concerns are rising about its ability to reflect current educational needs and industry progress (Türkistanlı, 2023). The digitalization and automation of shipping demand highly skilled and specialized crew, prompting a reconsideration of seafarers' roles and the need for education institutes to prepare students for future requirements (Demirel, 2020).

*"...Lack of familiarity. Some innovations on the bridge equipment were not introduced at school. Only the basics." (P5)*

One of the biggest challenges cadets faced was training on outdated systems. In school, they became familiar with older versions of ECDIS, IBS, and AIS, only to step onboard and realize that modern vessels were equipped with more advanced, integrated systems that looked and functioned differently. This meant they had to learn on the job, often relying on senior officers to guide them through unfamiliar system interfaces and complex features.

### ***Cadets' Adaptation***

To better understand how cadets adapted to the challenges of working on a digitalized navigational bridge, they shared their firsthand experiences of adjusting to real-world maritime operations. Their stories reveal the different ways they bridged the gap between classroom learning and onboard practice. The following are the results of the question, "How did you deal with the experiences/challenges encountered?".

Table 3. Cadets' Adaptation

Themes	Sub-themes	Codes
Learning through Self-Initiative	Self-Learning Strategies	Asking questions, Reading manual, Practicing
Learning through Mentorship Self-Learning Strategies	Guidance from Experienced Crew	Seeking senior officers assistance, Avoiding mistakes
Collaborative Learning Approach	Knowledge Acquisition Methods	Research, Asking officers, Learning equipment

**Theme 1. Learning through Self-Initiative**

While their academic training provided a strong foundation, the complexity of modern bridge systems demanded continuous learning and a proactive approach to keep up with evolving technologies. Cadets took the initiative to learn on their own, recognizing that adapting to digital navigation required more than just formal instruction. Traditional training methods are insufficient, and innovative approaches are required to develop practical and cognitive skills alongside digital competencies (Grancharova & Lutzkanova, 2023). One common strategy was exploring system manuals and digital resources during their free time. By studying system functionalities, shortcuts, and troubleshooting techniques, they were able to bridge the gap between theory and practice, gradually building confidence in operating the bridge.

*"...I just asked questions from my officers, read the manual, and kept on practicing." (P1)*

This theme highlights the importance of self-driven learning and adaptability in maritime education. As the industry continues to embrace digital transformation, future seafarers must cultivate a mindset of continuous improvement and independent problem-solving to thrive in a rapidly evolving environment. Ultimately, the ability to take initiative, seek knowledge, and apply learning in real-world situations is what prepares cadets for the challenges of modern navigation.

### ***Theme 2. Learning through Mentorship***

Stepping onto a digitalized navigational bridge for the first time felt overwhelming. The systems were more advanced than anything they had trained on, and real-world navigation came with complexities that couldn't be fully replicated in a classroom or simulator. In these moments, mentorship from experienced officers became a crucial lifeline. Effective mentorship involves open communication, encouragement, and collaborative peer-mentoring (Kato et al., 2021).

Rather than struggling alone, cadets turned to senior officers and bridge crew members for guidance. These mentors played a vital role in bridging the gap between theoretical knowledge and hands-on application. Mentors benefit from peer interactions, refining their expertise and management styles (Kato et al., 2021). For mentees, the process helps in finding their voice academically and emotionally, leading to empowerment (Conrad & Wardrop, 2024).

*"...I deal with this challenge by asking assistance from my senior officers onboard how to operate this equipment to avoid myself committing mistakes." (P4)*

Perhaps most importantly, mentorship fostered a culture of learning and growth. Cadets who actively sought feedback and engaged with their mentors found that the lessons extended beyond navigation—they learned about leadership, teamwork, and the mindset needed to adapt to rapid technological advancements in the maritime industry.

This theme highlights that while self-initiative is essential, mentorship remains one of the most powerful tools for cadets' professional development. The willingness of experienced officers to share their knowledge ensures that cadets are not just learning how to operate modern navigation systems—they're also developing the skills and confidence to thrive in an industry that is constantly evolving.

### ***Theme 3. Collaborative Learning Approach***

Collaborative learning (CL) is an educational approach that emphasizes student-centered activities and group work to solve problems or create products (Paul & Kundu, 2021). It offers numerous benefits, including improved academic skills and achievement (Dick et al., 2022). As the only cadet onboard, adapting to a digitalized navigational bridge was both an independent and collaborative effort. While cadets had to take personal initiative in learning, they also depended heavily on the guidance of senior officers and crew members to bridge the gap between theoretical knowledge and real-world application.

*"...Conduct research, but the most important strategy is to ask the officers how to use the navigational equipment, and they will teach me." (P3)*

Beyond direct mentorship, cadets learned by engaging in discussions and seeking feedback. They understood that navigating a modern bridge was not just about mastering technology but also about effective communication. By actively participating in briefings, reporting observations, and seeking clarification when faced with unfamiliar scenarios, they built confidence in handling digital systems while aligning their knowledge with industry best practices.

Additionally, cadets often referred to digital manuals, training modules, and onboard resources to reinforce their learning. With technology evolving

rapidly, they recognized the importance of continuous self-study, ensuring they were not only familiar with bridge systems but also prepared for any updates or variations in software interfaces.

This theme highlights that while cadets may be alone in their position, they are not learning in isolation. By embracing mentorship, engaging with experienced officers, and utilizing available resources, they develop the skills and adaptability needed to thrive in the modern maritime industry.

## **CONCLUSIONS AND RECOMMENDATIONS**

The research brings to light the growing divide between traditional classroom learning and the technological realities of modern ships—something that current maritime education systems must urgently address. As the maritime industry continues to embrace digital transformation, it becomes increasingly essential for maritime education to evolve alongside it. This research has shown that bridging the gap between traditional training and modern onboard technologies requires more than just updated equipment—it calls for a holistic shift in how we prepare future maritime professionals.

One of the most important takeaways is that while cadets are being taught foundational knowledge in school and through simulators, the complexity and pace of real-world navigation demand more than just textbook understanding. As technology at sea continues to evolve, so should the curriculum. It should include core human-technology interaction and real-life case studies of digital navigation challenges. To keep things relevant, schools should work closely with industry through regular feedback, advisory boards, technology expos, and collaborative research. And while technology is crucial, so is mentorship. Cadets thrive when they feel supported, and mentoring should be a formal, valued part of their learning experience.

For those looking to build on this research, future studies might explore how these early experiences shape cadets' confidence and performance later in their careers. It would also be valuable to compare the experiences of cadets who have had access to advanced simulators with those who haven't, or to investigate how instructors and onboard mentors help cadets adjust to digital navigation systems. Looking at different maritime schools across various regions or countries could also help uncover best practices and offer new ideas for making maritime training more relevant, practical, and supportive.

By embracing these changes, maritime institutions can better prepare their students for the realities of working with digitalized navigational bridges—improving not only safety and efficiency at sea but also opening doors for personal and professional growth in the maritime field.

## **FURTHER STUDY**

Future research should adopt a longitudinal, multi-site design that tracks cadets from classroom and simulator training through their initial sea appointments, comparing cohorts with differing levels of exposure to advanced digital-bridge technologies. Such studies should combine performance analytics, reflective journals, and in-depth interviews with cadets, instructors, and onboard mentors to reveal how early human-technology interaction

training, mentorship structures, and industry-academia collaboration influence confidence, decision-making quality, and safety outcomes over time. Cross-regional comparisons among maritime academies would further help distil best practices and contextual factors, ultimately guiding evidence-based reforms that align curricula, simulator design, and mentorship programs with the rapidly evolving demands of digital navigation.

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