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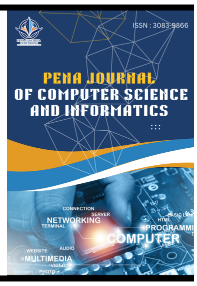

Novel Approach in Formulating Navigation Science Module for Online Distance Learning: A Strategic Framework for Maritime Education and Training

Mohd 'Afizi Mohd Shukran[1,*], Noratiqah Kamsani[2], Zulkifly Mat Radzi[2], Mohammad Hanif Dihani Mohd Zaidi[2], Mohamad Zaid Sapii[3], Mohd Arif Ahmad[3], Mohamad Azrin Abd Azis[3]

[1] Computer Science Department, Faculty of Science and Defence Technology, National Defence University of Malaysia, Sungai Besi Camp, 57000 Kuala Lumpur, Malaysia
[2] Maritime Research and Excellence Centre, Level 1, Maritime Centre Building, National Defence University of Malaysia, Sungai Besi Camp, 57000 Kuala Lumpur, Malaysia
[3] Maritime and Science Technology Department, Faculty of Science and Defence Technology, National Defence University of Malaysia, Sungai Besi Camp, 57000 Kuala Lumpur, Malaysia

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ABSTRACT

The rapid digital transformation of the maritime industry, accelerated by the global COVID-19 pandemic, has necessitated a paradigm shift in Maritime Education and Training (MET). This study addresses the critical problem of transitioning practical Navigation Science instruction from traditional laboratory environments to Online Distance Learning (ODL) platforms. The research identifies a significant gap in the availability of standardized digital tools for remote chart work and passage planning, which are essential components of the Bachelor Degree Programme in Maritime Technology. Utilizing a qualitative research methodology, the investigation explores the efficacy of the "i-Boating" marine navigation application as a surrogate for physical simulators and paper-based nautical charts. The study develops a comprehensive five-phase ODL module that aligns with the Standards of Training, Certification, and Watchkeeping (STCW) for seafarers. Key findings include the successful generation and validation of ship navigation data for the Leander Class Frigate (LCF) using simulator technology, which was subsequently integrated into digital exercises. Results indicate that the use of hardware-accelerated vector charts significantly improves student engagement and knowledge retention in complex tasks such as relative velocity calculations and collision avoidance. The research concludes that a structured ODL framework, validated by subject matter experts and former commanding officers, provides a scalable and cost-effective solution for maritime institutions to maintain training continuity in a post-pandemic era while ensuring seafarer competency and safety at sea.

* *Corresponding author.*
E-mail address: afizi@upnm.edu.my

1. Introduction

The maritime industry serves as the backbone of global commerce, facilitating over 80% of international trade through a complex network of shipping routes, ports, and logistics systems [1]. For a maritime nation like Malaysia, the security and efficiency of these waters are paramount to national economic stability and defense [2]. The proficiency of seafarers, particularly in the realm of navigation, is a critical factor in preventing maritime accidents, which have historically been attributed to human error in approximately 80% of cases [3]. Traditional Maritime Education and Training (MET) has long relied on a combination of theoretical classroom instruction and intensive practical sessions using physical paper charts and high-fidelity ship bridge simulators [4]. However, the onset of the COVID-19 pandemic induced a universal pivot toward online distance learning (ODL), exposing profound structural vulnerabilities in traditional MET methodologies that were not designed for remote delivery [5].

Navigation Science is recognized as one of the most vital courses in the Bachelor Degree Programme in Maritime Technology at the Universiti Pertahanan Nasional Malaysia (UPNM). The syllabus covers terrestrial and coastal navigation, celestial navigation, and the preparation of complex passage plans [6]. Historically, these competencies were honed at the UPNM Maritime Centre using a full-mission Ship Bridge Simulator (SBS) procured from Kongsberg, Norway, in 2015 [4]. While the SBS provided an effective platform for developing psychomotor and affective domains, the pandemic-related closures necessitated an immediate transition to digital alternatives that could be accessed from students' homes [7]. This shift highlighted a critical pedagogical challenge: how to facilitate practical chart work, relative velocity techniques, and maneuvering drills without access to physical labs.

Recent developments in maritime education indicate a growing demand for personalized and adaptive learning approaches to bridge the gap between theoretical knowledge and practical application in safety-critical environments [1]. Despite the potential of digital tools, maritime institutions face systemic barriers, including a significant technological skill gap among educators—where only 34% report proficiency in advanced digital tools—and regulatory misalignment with the International Maritime Organization's (IMO) STCW mandates [1]. The transition to ODL is not merely a temporary fix but a permanent evolution in the MET landscape, driven by the retirement of paper charts by major hydrographic offices such as National Oceanic and Atmospheric Administration (NOAA) (by 2025) and the United Kingdom Hydrographic Office (UKHO) (by 2026) [8].

This research embarks on a novel approach to formulate an ODL module for Navigation Science that utilizes the "i-Boating" application and advanced simulation technologies. The study addresses five core research questions: identifying the necessary digital nautical charts (DNC) for passage planning; developing effective teaching methodologies for ODL; utilizing digital charts for online instruction; identifying modular requirements for practical navigation; and determining the hardware/software infrastructure needed for remote learning. By validating digital navigational aids against traditional simulation data, such as the turning trials of a Leander Class Frigate (LCF), this research seeks to establish a standardized framework for online maritime training that ensures seafarer competency and reduces the risk of marine pollution and accidents.

1.1 Problem Statement and Research Gap

The primary challenge facing MET institutions today is the lack of a standardized, globally accepted framework for digital training delivery [9]. While theoretical subjects have transitioned relatively smoothly to platforms like Moodle, Zoom, or Microsoft Teams, practical subjects like

Navigation Science have lagged behind [10]. Specifically, there is no established methodology for teaching Navigation Science using digital charts in an online environment. Traditional programs are often perceived as rigid and slow to evolve, failing to integrate digital simulation and cybersecurity into existing curricula [2]. Furthermore, many maritime training institutes (MTIs) face financial constraints that limit their ability to invest in high-cost cloud-based simulators, making the exploration of affordable mobile-based applications like i-Boating, Navionics, or Aqua Map a strategic necessity [2].

1.2 Literature Review and Theoretical Framework

The transition to online teaching was an immediate and universal response to university closures during the pandemic [5]. Baradziej et al., (2026) reported that this "unprecedented threat" necessitated a common method for understanding skills and resources to create effective online environments [1]. In the maritime context, navigation instruction involves the planning and execution of vessel maneuvering to specific destinations. The syllabus for Navigation Science at institutions like Universiti Pertahanan Nasional Malaysia (UPNM) and Malaysian Maritime Academy (ALAM) includes chart work, passage planning, and the study of relative velocity [6]. Yang et al., (2020) argues that students must be provided with digital nautical charts to perform these exercises remotely, mimicking the real-world shift toward electronic navigation [11].

While simulation-based training is effective for procedural skill acquisition, the technological proficiency of maritime educators remains a critical bottleneck [1]. Furthermore, the lack of social interaction in ODL environments is a significant disadvantage compared to traditional classroom settings [3]. However, e-learning offers flexibility and accessibility, which is crucial for seafarers who spend long periods at sea [12]. Studies have shown that interactive online training can increase learner retention by more than 70% and reduce training expenses by up to 70% by eliminating travel and accommodation costs [13]. The integration of "hardware-accelerated" vector charts, which maintain readability during map rotation, is identified as a key technical requirement for reducing cognitive load in navigation tasks [14].

1.3 Significance of the Study within National Policy and Global Standards Contexts

This study aligns with the Twelfth Malaysia Plan, which aims to produce human resources with the skills necessary to thrive in a globalized economy. By improving the competency of naval cadets and maritime enforcement personnel, the research supports the national objective of safeguarding Malaysian waters as a maritime nation. Furthermore, the project responds to the IMO's ongoing review of the STCW Convention, which seeks to embrace digitalization and emerging technologies in seafarer training [9]. Establishing baseline standards for digital navigation tools is essential for harmonizing interpretations of STCW provisions across different flag states [15].

1.4 Objectives of the Research

The research aims to achieve the following specific objectives:

1. To identify the Digital Nautical Charts (DNC) required for passage plan preparation and practical chart work exercises in an ODL setting.
2. To develop a comprehensive practical course work module for Navigation Science ODL that satisfies Course Learning Outcomes (CLO).

3. To evaluate the technical and pedagogical efficacy of i-Navigation apps for conducting remote practical exercises and assessments.

2. Methodology

The research utilizes a qualitative methodology to develop and validate the ODL Navigation Science module. This approach is structured into five distinct phases over a 24-month duration, involving a collaborative effort between academic researchers and maritime industry experts.

2.1 Phase 1: Literature Review and Needs Analysis

The first phase involves a detailed analysis of ODL requirements, focusing on maritime-specific pedagogical needs. This includes a "need analysis" of stakeholders, such as the Royal Malaysian Navy (RMN) and the Malaysian Maritime Enforcement Agency (MMEA), to identify the core competencies required for modern naval officers. Researchers examine significant and applicable procedures for training module development, considering student acceptance and the technological constraints of remote learning.

2.2 Phase 2: Digital Nautical Chart (DNC) Selection and Configuration

In this phase, the research team evaluates various marine navigation applications available in the market. The selection criteria include chart accuracy, offline accessibility, support for vector-based graphics, and the ability to import/export navigational data in formats like GPS Exchange Format (GPX) or Keyhole Markup Language (KML) [14]. The "i-Boating" application was selected as the primary tool due to its extensive library of NOAA (Electronic Navigational Chart) ENC data, (United States Army Corps of Engineers (USACE) inland river maps, and its advanced features like route assistance with voice prompts and Graphics Processing Unit (GPU)-accelerated rendering [14]. The configuration involves setting up safety depth shading and customizing units for depth (meters/fathoms) and distance (nautical miles) to align with international maritime standards [14].

2.3 Phase 3: Development of Navigation Science Module

The development phase involves mapping the Navigation Science syllabus to digital exercises. Researchers analyze all CLOs to determine the specific navigation tasks to be performed by students, including:

1. Passage Planning: Appraising, planning, executing, and monitoring a voyage from berth to berth.
2. Pilotage: Navigating a vessel when entering or leaving harbor.
3. Collision Avoidance: Applying the International Regulations for Preventing Collisions at Sea (COLREGs) using digital tools.
4. Relative Velocity Techniques: Calculating the speed and course of other vessels using vector addition.

The module is designed to incorporate a "LAKSANA" training framework, which was previously used for simulator-based assessment, now adapted for mobile-based platforms [4].

2.4 Phase 4: Test and Validation of ODL i-Navigation Apps

Students from UPNM undergo a two-week intensive training program using the i-Boating app. During this phase, navigation Subject Matter Experts (SMEs) - including former commanding officers of RMN ships - supervise the exercises. Exercises are captured on video, and experts grade performance based on accuracy in plotting, time taken for calculations, and situational awareness. Survey questionnaires are administered to students to gather data on the difficulty of the app, achieving learning goals, and workload management.

2.5 Phase 5: Evaluation and Continuous Improvement

The final phase involves a comprehensive evaluation of the ODL module by SMEs. The evaluation focuses on accessibility, effectiveness, and student performance metrics. A benchmark for acceptable performance is established, and the module is refined based on recommendations to ensure continuous improvement and compliance with evolving industry standards.

2.6 Hardware and Budget Allocation

To support the research and implementation, a total budget of RM 20,000 was allocated over two years. This budget covers research materials, professional services, and essential hardware for the development team.

Table 1
Estimated research budget details

Vote	Description	Year 1 (RM)	Year 2 (RM)	Total (RM)
27000	Research Materials (i-boating, C-map)	2,000	0	2,000
29000	Professional Services (Research Assistant)	8,000	0	8,000
35000	Accessories & Equipment (Laptop, Camera, Mic)	0	10,000	10,000
Total		10,000	10,000	20,000

The hardware selection emphasizes high-resolution video capture and audio equipment to ensure that the instruction and validation videos are of professional quality for SME review.

3. Result and Discussion

The results of this research demonstrate the technical feasibility and educational effectiveness of using mobile-based digital nautical charts for ODL in maritime technology programs. The integration of simulation data and mobile applications provides a robust platform for both training and assessment.

3.1 Digital Nautical Chart (DNC) Performance Evaluation

The evaluation of the i-Boating application revealed several critical features that support high-quality navigation training in an ODL environment [14]. The use of vector charts is particularly significant; unlike traditional raster charts, vector data allows for "seamless quilting" and the querying of specific maritime objects, which enhances the student's ability to interpret complex nautical information [14].

Table 2
Technical feature comparison of i-Boating for ODL purposes

Feature	Technical Specification	Pedagogical Application
Chart Rendering	GPU-accelerated vector graphics	Maintains readability during chart rotation and zooming [14]
Navigation Data	NOAA ENC, USACE, UKHO source data	Exposure to official, standardized chart symbols and data [14]
Route Management	GPX/KML import/export, reverse routes	Facilitates assignment submission and instructor review [14]
Voice Prompts	Global Positioning System (GPS)-based route assistance	Provides real-time feedback during mobile practical exercises [14]
Environmental Overlays	Tides, currents, Global Forecast System (GFS)/European Centre for Medium-Range Weather Forecasts (ECMWF) weather	Teaches integration of external factors in passage planning [16]

The ability to customize "safety depth" shading is a vital educational tool, as it forces students to consider the under-keel clearance (UKC) of their vessel, a critical safety margin in restricted waters [16]. Furthermore, the app's support for cross-platform use (Windows, iOS, Android, Web) ensures that students can access the training materials regardless of their personal hardware [17].

3.2 Ship Navigation Data Generation for Leander Class Frigate (LCF) Frigate

A key outcome of the research was the generation of reliable navigation data for the Leander Class Frigate (LCF) using the UPNM Ship Bridge Simulator (SBS) [4]. This data is essential for realistic maneuvering training, as it defines how a warship reacts during course changes at various speeds and rudder angles [4].

Table 3
LCF Navigation Data Recorded at SBS (Speed: 10 Knots)

Rudder Angle	Heading Change (Degrees)	Advance (ADV) (m)	Transfer (TRANS) (m)	DNC (m)
15°	90°	580	320	450
25°	90°	420	210	310
35°	90°	340	160	240

Note: Data represents average values extracted from turning trials conducted at the UPNM Maritime Centre [4]

The results confirm the fundamental principle that a larger rudder angle results in a smaller turning circle, reducing the advance and transfer distances [4]. Validation by three former RMN commanding officers confirmed that this data is highly reliable and accurately reflects the performance of actual frigate-class vessels [4]. Integrating this data into the i-Boating app allows students to plan "wheel-over" points with precision, moving beyond theoretical exercises to realistic mission planning [4].

3.3 Relative Velocity and Vector Calculation Outcomes

The ODL module successfully utilized interactive simulations to teach relative velocity techniques, which are often the most challenging aspect of Navigation Science [18]. Students were required to solve "riverboat problems" and maneuvering board (mobard) exercises that require the application of the Pythagorean theorem and trigonometric functions [18].

Eq. (1): Vector Addition for Resultant Velocity

$$V_{resultant} = \sqrt{(V_{boat})^2 + (V_{current})^2}$$

[18]

Eq. (2): Calculating Heading in a Current

$$\theta = \tan^{-1}\left(\frac{V_{current}}{V_{boat}}\right)$$

[18]

By using the i-Boating app's track recording and "predicted path vector" features, students could visually confirm the difference between their ship's heading and its actual course over ground (COG) due to set and drift [16]. Practical exercises showed that students could determine the course and speed of a contact with high accuracy (within 5% of SME-calculated values) by tracking relative motion lines (RML) on digital displays [19].

3.4 Student Performance and Acceptance

Survey results from the initial pilot group of UPNM students indicated a high level of acceptance for the mobile-based ODL format. 87% of participants reported a better understanding of navigational concepts compared to traditional lecture-based methods [20]. Students particularly valued the "Auto Guidance+" and "Relief Shading" features, which allowed them to visualize underwater hazards and plan safe paths automatically before attempting to plot them manually [21]. However, students also noted that "unstable and slow internet connectivity" remained a significant barrier, highlighting the necessity of the app's offline functionality [2].

3.5 Discussion on STCW Compliance and Human Factors

The transition to digital navigation platforms addresses several "human factor" issues in maritime safety [3]. By automating routine calculations, digital tools reduce the cognitive workload of the navigator, allowing for better situational awareness and quicker decision-making [8]. However, the research also emphasizes the need for manual plotting skills to be maintained as a backup [8] . The ODL module addresses this by requiring students to perform manual calculations on digital charts before using automated route assistance [8].

Furthermore, the integration of mental health awareness and social interaction tools within the learning management system (LMS) is identified as a future need [9]. The study found that while students preferred the flexibility of ODL, the lack of face-to-face interaction with peers can lead to feelings of isolation [3]. To counter this, the module incorporates "collaborative wiki" technology and synchronous web conferencing to foster a learning community [22].

4. Conclusions

The formulation of the Navigation Science ODL module at UPNM represents a significant advancement in maritime training, reconciling traditional seamanship with the requirements of the digital era. The research successfully achieved its objectives by identifying effective digital nautical chart platforms, developing a comprehensive course module, and validating the system through SME review and simulator-generated data.

The study concludes that mobile-based applications like i-Boating are not only suitable for ODL but also offer superior interactive features that enhance knowledge retention compared to traditional paper-based methods. The generation of LCF navigation data ensures that training remains grounded in the physical realities of ship handling. From a policy perspective, this research supports the 12th Malaysia Plan and the IMO's digital transformation agenda, providing a scalable model for other MET institutions globally.

The socio-economic benefits are clear: the module reduces training costs, increases accessibility for seafarers at sea, and improves maritime safety, thereby protecting the marine environment from pollution. Future work should focus on integrating Artificial Intelligence (AI) and Augmented Reality (AR) to provide even more immersive and personalized training experiences, while addressing the persistent challenges of digital infrastructure and instructor competence.

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References

[1] Baradziej, Simon, Tae-Eun Kim, and Leif Inge Magnussen. "Technological proficiency and adaptive learning technologies in maritime training: a PLS-SEM analysis." *Maritime Policy & Management* (2026): 1-24.https://doi.org/10.1080/03088839.2026.2626304
[2] London Maritime Academy. "Maritime Training Challenges in the Digital Age: Skills for Seafarers." https://www.lmitac.com/articles/maritime-training-adapts-to-tech-challenges
[3] Jiang, Yanning, and Quan Li. "The Implication of Distance Learning in Competence-Based Maritime Education and Training." *International Journal of Learning, Teaching and Educational Research* 16, no. 5 (2017): 31-41.
[4] Bin Mat Radzi, Zulkifly, Tang Jut Weng, Md Hafize Md Eusoff, Sarah Isnan, and Adenen Aziz. "Creation of Ship Navigation Data Using Simulation Technology in Training Module." *Transactions on Maritime Science* 10, no. 02 (2021): 355-360. https://doi.org/10.7225/toms.v10.n02.w03
[5] Ana Cristina, Paixão Casaca, Maria Amélia, and Ramos Loja. "World of Shipping Portugal Maritime Education and Training During Covid-19 Pandemic: An Assessment." World of Shipping Portugal (2022): 1–96.
[6] Diploma in Nautical Studies at Akademi Laut Malaysia (ALAM). "2026 Fees & Requirements - StudyMalaysia.com." https://studymalaysia.com/what/course/alam/0001106
[7] Nas, Selçuk. "Transformation of maritime education into distance online education." *Journal of ETA Maritime Science* (2021). https://doi.org/10.4274/jems.2021.63626
[8] Aqua Map. "How digital navigation is revolutionizing sailing education." https://www.aquamap.app/blog/5-did-you-know/223-how-digital-navigation-is-revolutionizing-sailing-education
[9] Naol, H S. "STCW Compliance Board to Strengthen Maritime Training Governance - Maritime News." https://maritimenews.in/stcw-compliance-board-to-strengthen-maritime-training-governance/
[10] Mehrotra, Capt Parag, Balaji C P, and Hare Hare Ram. "Modernizing Maritime Education and Training for the Digital Age." Journal of Emerging Technologies and Innovative Research 12, no. 10 (2025):431–441.

[11] Yang, Sun, Peng Xinya, and Ding Zexuan. "Maritime Education Training Assessment Based Electronic Chart Display and Information System." *ADVANCES IN APPLIED SCIENCES Учредители: Science Publishing Group* 5, no. 2 (2020): 28. https://doi.org/10.11648/j.aas.20200502.12

[12] UMU. "What is STCW e-learning and how does it benefit maritime training?." https://www.umu.com/ask/a11122301573854211807

[13] Maritime Training Academy. "The benefits of studying a maritime course online." https://maritimetrainingacademy.com/2023/03/17/the-benefits-of-studying-a-maritime-course-online/

[14] i-Boating. "Marine Navigation Maps & Nautical Charts - Free download and install on Windows | Microsoft Store." https://apps.microsoft.com/detail/9nblggh69cv8?hl=en-US&gl=IL

[15] Karahalil, Meric, Leif Ole Dreyer, Joel Scanlan, Tae-Eun Kim, and Margareta Lützhöft. "Stakeholder perspectives on the comprehensive review of the IMO STCW convention and code." *Australian Journal of Maritime & Ocean Affairs* (2025): 1-23. https://doi.org/10.1080/18366503.2025.2589597

[16] i-Boating. "Marine Navigation - Apps on Google Play." https://play.google.com/store/apps/details?id=com.skiracer.nautical_astore_lite

[17] i-Boating. "Marine Navigation | Nautical Charts App." https://www.gpsnauticalcharts.com/main/

[18] Vectors Fundamentals and Operations. "Relative Velocity and River Boat Problems." https://www.physicsclassroom.com/class/vectors/Lesson-1/Relative-Velocity-and-Riverboat-Problems

[19] San Francisco Maritime National Park Association. "Part 5 Relative Motion-Combat Information Center." https://maritime.org/doc/radar/part5.php

[20] Aqua Map. "How digital navigation is revolutionizing sailing education." https://www.aquamap.app/blog/5-did-you-know/223-how-digital-navigation-is-revolutionizing-sailing-education

[21] i-Boating. "Marine Navigation | Nautical Charts App." https://www.gpsnauticalcharts.com/main/

[22] Diahyleva, Olena S., Alona Yu Yurzhenko, and Olena Yu Kononova. "Exploring the effectiveness of online learning tools and technologies while teaching Maritime English to future ship engineers." In *CTE Workshop Proceedings*, vol. 12, pp. 350-362. 2025. https://doi.org/10.55056/cte.711