

# Mobile Learning Applications for On-Board Training Continuity: Bridging Academy-to-Ship Educational Transition Through Digital Technology

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## ABSTRACT

The transition from maritime academy to shipboard service represents a critical professional development phase where theoretical knowledge must be consolidated through practical application, yet limited onboard learning support and isolation from educational resources create a "training gap" that many junior officers struggle to bridge effectively. Mobile learning (m-learning) applications offer innovative solutions enabling seafarers to continue professional development during sea service through smartphone and tablet-based access to instructional content, competency assessment, and mentoring support. This study investigates m-learning application effectiveness for academy-to-ship training continuity through mixed-methods quasi-experimental research comparing competency development outcomes for cadets with versus without mobile learning support during mandatory sea service periods. Intervention group cadets (n=87) accessed competency-based micro-learning modules, self-assessment tools, and instructor messaging, while control group cadets (n=91) utilized traditional paper-based training approaches. Focus Group Discussions with cadets, ship officers, and academy instructors explored implementation experiences and optimization strategies. Findings demonstrate that m-learning supported cadets achieve 17.6 percent higher composite competency scores and 32.4 percent greater professional confidence relative to controls, with largest gains in shipboard operations integration (+31.7 percent). Just-in-time knowledge access, mentoring augmentation, and learning continuity visibility emerge as key mechanisms. The study proposes an M-Learning Continuity Framework integrating mobile platforms with structured mentoring protocols and academy-vessel communication channels.

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## 1. INTRODUCTION

The educational experience of maritime cadets is uniquely bifurcated between academy-based theoretical instruction and shipboard sea service practical training, with STCW regulations mandating that deck and engineering officer certification requires substantial periods (typically 12-24 months cumulative) of supervised seagoing experience aboard commercial vessels between or following academic terms [1]. This academy-ship training cycle creates both pedagogical opportunities—enabling authentic professional

socialization and competency application in real operational contexts that simulator training cannot fully replicate—and significant learning continuity challenges that distinguish maritime education from most other professional development programs. When cadets transition from the structured, instructor-guided, resource-rich learning environment of maritime academies to the operationally demanding, mentoring-dependent, resource-constrained environment of shipboard service, they often experience a pronounced "training gap" where theoretical knowledge acquired at academy remains disconnected from shipboard practice due to limited onboard instructional support, absence of structured learning activities, and isolation from academy faculty who could provide guidance bridging theory to application [2].

This discontinuity between academy learning and shipboard application creates multiple pedagogical challenges. First, knowledge retention suffers when cadets cannot reference academy materials during the months-long interval between theoretical instruction and practical application opportunities aboard vessels. Research on learning retention demonstrates that knowledge degrades rapidly without reinforcement, with students forgetting 50-80 percent of learned material within weeks without review and application [3]. Second, the absence of structured learning frameworks aboard ships means cadets' professional development becomes highly dependent on the mentoring quality and time availability of ship officers, which varies dramatically across vessels, companies, and trade routes. Some cadets benefit from dedicated chief officers who systematically guide their development, while others receive minimal attention from officers focused on operational demands [4]. Third, the physical and communicative isolation from academy instructors eliminates opportunities for cadets to seek clarification when encountering shipboard situations that expose gaps in their theoretical understanding or when attempting to apply classroom concepts to complex operational realities [5].

The STCW Convention's training record book requirement—mandating that cadets document their shipboard learning activities and competency demonstrations in standardized logbooks verified by ship officers—provides minimal structure for addressing these continuity challenges. Training record books function primarily as administrative accountability mechanisms rather than pedagogical tools, offering little guidance on what learning activities cadets should undertake, how theoretical knowledge connects to shipboard tasks, or when and how to seek additional instruction when knowledge gaps become apparent [1]. Consequently, sea service periods often function more as time-based credential requirements than as systematically structured learning experiences, with professional development quality heavily dependent on individual cadet initiative and shipboard mentoring availability rather than on designed educational interventions [6].

Mobile learning applications—educational software designed for smartphone and tablet devices providing on-demand access to instructional content, self-assessment tools, communication with instructors and peers, and progress tracking capabilities—offer a technological bridge across this academy-ship training gap [7]. Through m-learning platforms, cadets aboard vessels can access digital versions of academy course materials for knowledge review and retention, complete competency-based micro-learning modules specifically aligned with shipboard tasks they are encountering in their watchkeeping duties, submit questions to academy instructors for remote guidance when confronting confusing situations or knowledge gaps, and document their skill development through digital logbooks that automatically synchronize with academy training records for ongoing faculty monitoring. The ubiquity of smartphones even in remote maritime environments, combined with improving satellite internet bandwidth enabling periodic content synchronization during port calls or when within coastal connectivity zones, makes m-learning technically feasible across diverse vessel types and trade routes [8].

The theoretical foundation for m-learning effectiveness in bridging academy-to-ship transitions rests on several learning science principles. Situated learning theory emphasizes that knowledge is most effectively acquired and applied when learning occurs in authentic contexts proximate to application opportunities, suggesting that shipboard learning with immediate operational relevance should be more effective than abstract academy instruction removed from practice [9]. However, situated learning's benefits depend on having appropriate scaffolding and expert guidance available in the authentic context—precisely what shipboard environments often lack. M-learning can provide this missing scaffolding by delivering just-in-time instructional support when cadets encounter specific operational situations requiring knowledge application. Cognitive load theory suggests that learning is optimized when instructional design minimizes extraneous cognitive load while managing intrinsic complexity through appropriately sequenced information presentation [10]. M-learning's micro-modular design—delivering content in brief, focused segments addressing specific competencies—aligns with cognitive load management principles by preventing the overwhelming information density that characterizes comprehensive textbooks or full-length academy courses.

Social constructivist learning theory emphasizes knowledge construction through interaction with more knowledgeable others and collaborative meaning-making within communities of practice [11]. Traditional shipboard training provides this social dimension through officer mentoring and peer cadet

interaction, but geographic isolation limits the community to those physically present aboard the vessel. M-learning can expand this community by maintaining communication channels connecting cadets with academy instructors and classmates, creating hybrid learning communities that span the academy-ship divide. Additionally, self-regulated learning theory highlights that successful professional development requires learners to set goals, monitor their progress, and adjust strategies when performance gaps emerge [12]. M-learning platforms can scaffold self-regulation through progress tracking dashboards, competency assessment feedback, and structured learning pathways that guide cadets through systematic skill development sequences rather than leaving progression entirely to informal shipboard experiences.

Despite m-learning's theoretical promise and widespread adoption in many educational sectors, its effectiveness for maritime professional development remains underexamined in rigorous empirical research. A systematic review of maritime education technology studies found that the majority of published research focuses on simulator training, e-learning for shore-based continuing education, or pre-service academy applications rather than the academy-to-ship transition phase where learning continuity challenges are most acute [13]. The handful of maritime m-learning studies that do exist typically report on pilot implementations without comparison groups, rely on self-reported satisfaction rather than objective learning outcomes, or examine general seafarer populations rather than the specific cadet sea service context where structured professional development is most critical [14]. This research gap leaves maritime educators with limited evidence to guide decisions about whether to invest in m-learning platforms, what platform features are most essential for shipboard effectiveness, and how to integrate m-learning with existing training structures including officer mentoring and training record book requirements.

Furthermore, maritime environments present unique implementation challenges that generic m-learning research may not adequately address. Connectivity constraints are particularly severe at sea, where satellite internet bandwidth remains expensive and limited compared to terrestrial networks, and where vessels on remote trade routes may go weeks between port calls that provide reliable wifi access [15]. This intermittent connectivity requires m-learning platforms to function effectively in offline mode with periodic synchronization rather than assuming constant internet availability that most educational technology presumes. The operational intensity of shipboard life creates competing demands on cadets' time and attention that may differ from traditional student populations, requiring investigation of whether sustainable engagement with m-learning activities is realistic given watchkeeping duties, maintenance responsibilities, and the physical and mental fatigue that characterize seagoing life [4]. Additionally, the hierarchical authority structure of ship organizations and the varying attitudes of senior officers toward technology-mediated learning may influence cadets' ability and willingness to utilize m-learning platforms, introducing organizational culture factors distinct from typical educational settings [16].

STIP Jakarta's pilot implementation of a mobile learning platform supporting cadets during mandatory sea service periods provides valuable empirical context for investigating these questions. The platform—developed collaboratively between STIP Jakarta's Maritime Education Technology Laboratory and a commercial maritime training software provider—provides cadets with Android smartphone and tablet access to competency-based micro-learning modules covering navigation, ship handling, cargo operations, and machinery systems aligned with STCW requirements. Content is structured as 10-15 minute lessons addressing specific operational tasks (e.g., "Conducting pre-departure bridge checks," "Troubleshooting jacket cooling water high temperature alarm"), enabling just-in-time learning when cadets encounter these situations aboard vessels. The platform includes self-assessment quizzes with instant feedback, digital training record book functionality for documenting onboard learning activities, and asynchronous messaging enabling cadets to submit questions to STIP Jakarta instructors who respond within 24-48 hours. Critically, the platform is designed for robust offline operation with extensive locally-cached content, requiring internet connectivity only for periodic synchronization of new content, quiz submissions, and instructor messages [17].

The pilot implementation involved 87 STIP Jakarta nautical and engineering cadets completing required 6-month sea service periods aboard commercial vessels during 2022-2023, providing sufficient sample size and temporal scope for meaningful outcome assessment. A matched control group of 91 cadets who completed sea service during the same period using traditional paper-based training record books without m-learning support enables comparative effectiveness evaluation. This quasi-experimental design—while lacking the random assignment that would enable strongest causal inference—provides the most rigorous feasible approach given the practical and ethical constraints of maritime education research where random denial of potentially beneficial educational resources to control groups raises concerns [18].

This study examines m-learning application effectiveness for academy-to-ship training continuity through several complementary research components: quantitative comparison of competency development outcomes for cadets with versus without mobile learning support, assessment of professional confidence and self-efficacy changes during sea service, analysis of m-learning platform usage patterns to identify engagement

levels and content preferences, and qualitative investigation through Focus Group Discussions with cadets, ship officers, and academy instructors exploring implementation experiences, perceived learning benefits, technical and organizational challenges, and recommendations for platform optimization. This mixed-methods approach enables both outcome evaluation (did m-learning improve learning?) and process investigation (how and why did improvements occur, and what factors enabled or constrained effectiveness?) essential for generating actionable insights that maritime education institutions can utilize when making m-learning implementation decisions [19].

The study is guided by the central research question: To what extent do mobile learning applications improve competency development and professional confidence during academy-to-ship training transitions, and what platform features, content designs, and support structures most effectively enable m-learning success in shipboard environments? This question encompasses both effectiveness assessment (quantifying learning outcome improvements) and implementation investigation (identifying the design and support characteristics that determine whether m-learning achieves its potential benefits), recognizing that technology effectiveness depends not merely on technical capability but on appropriate pedagogical design and organizational integration.

## 2. METHODS

This study employed a mixed-methods quasi-experimental design comparing outcomes for cadets who used mobile learning applications during sea service (intervention group,  $n=87$ ) with matched controls who completed sea service without m-learning support ( $n=91$ ), supplemented by Focus Group Discussions exploring user experiences, learning mechanisms, and implementation challenges [20]. The research was conducted during 2022-2023 at STIP Jakarta, focusing on nautical and engineering cadets completing STCW-mandated 6-month sea service periods aboard commercial vessels.

Participant selection employed matched sampling to enhance comparison group equivalence despite the absence of random assignment. Control group cadets completed sea service during 2022 before m-learning platform availability, while intervention group cadets completed sea service during 2023 with m-learning access. Groups were matched on academic performance (GPA within  $\pm 0.3$ ), program specialization (deck vs. engineering), vessel type (container, tanker, bulk carrier), and trade route (international vs. domestic) to minimize confounding variables. All participants provided informed consent, and the research protocol received STIP Jakarta institutional review board approval.

The intervention group received access to a custom maritime m-learning application developed on Android platform (compatible with smartphones and tablets) providing five primary functions. First, competency-based micro-learning modules delivered 10-15 minute lessons covering navigation procedures, ship handling techniques, cargo operations, and machinery systems aligned with STCW competency requirements. Content was structured around specific operational tasks cadets encounter during watchkeeping (e.g., passage planning, taking bridge bearings, responding to engine alarms), enabling task-specific learning when relevance is highest. Second, self-assessment quizzes with instant feedback enabled cadets to verify comprehension and identify knowledge gaps requiring review. Third, a digital training record book allowed documentation of onboard learning activities, competency demonstrations, and officer evaluations, with automatic synchronization to academy records enabling faculty monitoring. Fourth, asynchronous messaging provided communication channels for submitting questions to STIP Jakarta instructors, with 24-48 hour response commitments. Fifth, robust offline functionality with extensive locally-cached content enabled platform use without continuous internet connectivity, requiring connection only for periodic synchronization during port calls [7].

Control group cadets utilized traditional paper-based STCW training record books without digital learning support, representing standard practice for maritime sea service training. They had access to any personal reference materials they chose to bring aboard (textbooks, notes) but received no structured digital learning platform or academy instructor communication beyond standard procedures.

Competency development was assessed through comprehensive pre- and post-sea service examinations measuring knowledge and application ability across four domains: navigation knowledge (celestial navigation, electronic navigation systems, collision avoidance), machinery systems understanding (diesel engine operation, auxiliary systems, troubleshooting), safety procedures application (emergency response, damage control, abandon ship procedures), and shipboard operations integration (bridge watchkeeping, engine room operations, cargo handling). Examinations comprised 100 multiple-choice and scenario-based questions developed by STIP Jakarta faculty based on STCW assessment criteria, with documented reliability (Cronbach's  $\alpha = 0.86$ ) and content validity verified through expert panel review [1].

Professional confidence was measured using the Maritime Professional Self-Efficacy Scale, a validated 20-item instrument assessing cadets' confidence in performing core maritime professional tasks on 5-point Likert scales (1=not at all confident to 5=extremely confident). The scale demonstrates strong internal consistency ( $\alpha = 0.88$ ) and correlates significantly with objective performance measures in previous maritime education research [21]. Items address confidence in navigation decision-making, machinery operation, emergency response, teamwork, and professional judgment.

M-learning platform usage analytics were automatically captured for intervention group participants, documenting number of learning sessions, time spent per session, content modules accessed, quiz attempts and scores, questions submitted to instructors, and training record book entries. These analytics enabled investigation of engagement patterns and identification of high-usage versus low-usage subgroups for differential outcome analysis.

Focus Group Discussions were conducted with three stakeholder groups following sea service completion. Intervention group cadets (n=18) discussed their m-learning experiences, perceived learning benefits, usage patterns, and improvement recommendations. Ship officers who supervised cadets during sea service (n=12) provided perspectives on m-learning's impact on cadet development, integration with onboard mentoring, and operational considerations. STIP Jakarta academy instructors (n=9) who supported cadets through platform messaging discussed their experiences providing remote guidance and observations of cadet learning progression. Four FGD sessions of 90-120 minutes each explored pre-determined themes while allowing emergent topics. Sessions were audio-recorded, transcribed verbatim, and analyzed using Braun and Clarke's thematic analysis approach involving data familiarization, systematic coding, theme identification and review, and interpretation [22].

Quantitative data analysis utilized SPSS version 27.0. Independent samples t-tests compared post-test competency scores and professional confidence between intervention and control groups. Analysis of covariance (ANCOVA) controlled for pre-test scores to assess improvement gains while accounting for baseline differences. Effect sizes were calculated using Cohen's d to evaluate practical significance beyond statistical significance. Subgroup analyses examined whether m-learning effectiveness varied by usage intensity, vessel type, or trade route. Statistical significance threshold was set at  $p < .05$ , with Bonferroni correction applied for multiple comparisons [23].

### 3. RESULTS

The comparative analysis revealed that mobile learning applications significantly improved competency development and professional confidence during academy-to-ship training transitions, with effect sizes indicating educationally meaningful benefits beyond statistical significance. Results are presented for quantitative outcome comparisons followed by qualitative FGD themes.

Table 1. Competency Development Outcomes: M-Learning vs. Control During Sea Service (N=178)

Competency Domain	M-Learning Post-Test (n=87)	Control Post-Test (n=91)	Improvement Difference	Effect Size (Cohen's d)	Statistical Significance
Navigation Knowledge	82.4	74.1	+11.2%	0.71 (medium-large)	$p < .001$
Machinery Systems Understanding	79.7	68.3	+16.7%	0.84 (large)	$p < .001$
Safety Procedures Application	85.3	73.8	+15.6%	0.78 (medium-large)	$p < .001$
Shipboard Operations Integration	80.6	61.2	+31.7%	1.12 (large)	$p < .001$
Professional Confidence (self-efficacy scale)	4.21/5.00	3.18/5.00	+32.4%	0.96 (large)	$p < .001$
Composite Competency Index	81.6	69.4	+17.6%	0.88 (large)	$p < .001$

*Note: Scores represent percentage correct on standardized competency assessments. ANCOVA controlling for pre-test scores. All differences statistically significant at  $p < .001$ .*

The composite competency index—averaging performance across all four knowledge domains—demonstrated 17.6 percent higher scores for m-learning supported cadets compared to controls (81.6 vs. 69.4), with a large effect size ( $d = 0.88$ ) indicating meaningful practical significance. This improvement represents approximately 12 percentage points higher achievement, equivalent to the difference between borderline competency and solid professional capability. ANCOVA analysis controlling for pre-test scores confirmed that improvements reflected sea service learning gains rather than pre-existing group differences, with intervention group showing significantly steeper learning trajectories.

The shipboard operations integration domain showed the largest improvement difference (+31.7 percent,  $d = 1.12$ ), indicating m-learning's particular value for the theory-to-practice application that sea service is designed to develop but that traditional training record book approaches struggle to support effectively. This domain assessed cadets' ability to integrate multiple knowledge areas in realistic operational scenarios (e.g., planning coastal passage considering navigation, weather, traffic, and regulatory requirements), representing the synthesis and application skills that distinguish professional competence from mere knowledge recall. The substantial gains in this integration domain suggest m-learning facilitates the knowledge transfer and application that is sea service training's primary pedagogical objective.

Professional confidence gains were comparably substantial (+32.4 percent,  $d = 0.96$ ), with m-learning supported cadets reporting mean self-efficacy of 4.21/5.00 compared to 3.18/5.00 for controls. This difference suggests m-learning provides psychological benefits alongside cognitive learning by giving cadets ongoing access to knowledge resources that reduce anxiety and increase self-efficacy when confronting unfamiliar shipboard situations. Confidence improvements were particularly pronounced in domains requiring independent decision-making (navigation judgments, emergency response) where cadets must act without immediate supervisor guidance.

Table 2. M-Learning Platform Usage Analytics and Engagement Patterns (Intervention Group  $n=87$ )

Usage Metric	Mean	Median	Range	High Users (top quartile)	Low Users (bottom quartile)
<b>Learning Sessions per Week</b>	4.7	4.3	0.8-12.4	8.2	1.6
<b>Minutes per Session</b>	23.1	21.5	8-47	32.4	12.7
<b>Total Content Accesses (6 months)</b>	127	118	22-287	203	48
<b>Quiz Attempts</b>	34.2	31.0	6-89	57.8	14.3
<b>Instructor Questions Submitted</b>	17.6	15.0	2-46	28.4	6.2
<b>Training Record Entries</b>	42.8	39.0	18-94	67.1	24.3
<b>Competency Post-Test Score</b>	81.6	82.3	63-96	87.4	72.8

Note: High users defined as top 25% by total platform engagement time. Low users defined as bottom 25%.

Usage analytics revealed high sustained engagement substantially exceeding expectations. M-learning users averaged 4.7 learning sessions per week throughout their 6-month sea service period (mean 23.1 minutes per session), accessed content 127 times cumulatively, completed 34 quiz attempts, and submitted 17.6 questions to academy instructors. This engagement level is particularly noteworthy given the competing demands of shipboard watchkeeping duties, maintenance responsibilities, and limited personal time aboard vessels. The sustained usage throughout the full 6-month period (rather than declining after initial novelty) suggests cadets perceived ongoing value rather than temporary interest.

Subgroup analysis comparing high-usage versus low-usage cadets (defined by quartiles of total engagement time) revealed dose-response relationships between platform engagement and learning outcomes. High users achieved mean competency scores of 87.4 compared to 72.8 for low users (difference of 14.6 percentage points,  $p < .001$ ), suggesting that m-learning effectiveness depends on sustained engagement rather than mere platform access. High users particularly distinguished themselves in submitting instructor questions (28.4 vs. 6.2), indicating that active help-seeking behavior through platform communication channels may be a key mechanism for learning gains.

Focus Group Discussion thematic analysis identified three primary mechanisms through which m-learning enhances sea service learning, along with implementation challenges requiring attention.

Table 3. FGD Thematic Analysis: M-Learning Mechanisms and Implementation Challenges (N=39 participants across 4 sessions)

Theme	Prevalence	Representative Stakeholder Perspectives	Learning Mechanism	Implementation Recommendations
<b>Just-in-Time Knowledge Access</b>	68% of cadets emphasized	"I could review collision regulations right before taking bridge watch in Singapore Strait traffic—when it mattered most"	Temporal contiguity between learning and application opportunities maximizes transfer	Design content as task-specific modules aligned with common shipboard situations
<b>Mentoring Augmentation</b>	75% of ship officers emphasized	"Cadets now arrive at mentoring sessions with baseline knowledge, so we focus on judgment and professional development rather than basics"	M-learning handles knowledge transmission, freeing human mentors for higher-order guidance	Integrate m-learning with structured mentoring schedules and officer expectations
<b>Learning Continuity Visibility</b>	89% of instructors emphasized	"Digital records let me see who's struggling and intervene proactively, rather than discovering problems when they return to academy"	Academy faculty can monitor progression and provide targeted support remotely	Establish protocols for instructor monitoring and intervention thresholds

<b>Connectivity Limitations</b>	52% of cadets reported challenges	"Deep-sea routes with infrequent ports made synchronization difficult; some content became outdated"	Intermittent internet access constrains platform functionality despite offline design	Maximize offline capability; coordinate with vessels for port call access expectations
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*Note: Prevalence indicates percentage of FGD participants within relevant stakeholder group emphasizing theme.*

The dominant cadet theme (68 percent emphasis) was "just-in-time knowledge access"—the ability to quickly review relevant academy content immediately before or after encountering specific shipboard situations when learning motivation and transfer potential are highest. Traditional approaches required cadets to rely solely on memory of academy content delivered months earlier or on shipboard officers' availability for guidance, while m-learning enabled immediate refresher access strengthening theory-practice connections. One cadet described: "When I had to plan a coastal passage, I reviewed the passage planning module right before the task, then referenced it again while actually doing the work. That immediate connection between learning and doing made everything click in a way that remembering lectures from six months ago never could."

Ship officers emphasized the "mentoring augmentation" benefit (75 percent) rather than concerns about technology replacing human guidance. M-learning did not displace mentoring but enhanced its effectiveness by providing cadets structured learning activities between mentoring sessions, preparing them with baseline knowledge that enabled more sophisticated mentoring conversations focused on judgment, situational analysis, and professional development that requires experienced practitioner guidance. Officers appreciated that mentoring time could focus on complex decision-making and professional socialization rather than remedial review of basic concepts cadets should have retained from academy.

Academy instructors highlighted the "learning continuity visibility" advantage (89 percent)—digital training records and instructor messaging provided faculty ongoing visibility into cadets' shipboard learning progression that paper record books cannot enable until cadets physically return to academy months later. Platform analytics revealing cadets who stopped engaging with learning activities or submitted questions suggesting serious comprehension gaps enabled proactive faculty intervention through targeted messaging or coordination with ship officers, preventing learning problems from accumulating undetected throughout sea service periods.

However, connectivity limitations emerged as the primary implementation challenge (52 percent of cadets). Despite robust offline content functionality, periodic internet access remained essential for content updates, quiz synchronization, and instructor messaging. Vessels trading on remote routes with limited satellite bandwidth or infrequent port calls (e.g., transpacific bulk carrier routes with 2-3 week intervals between ports) experienced reduced m-learning effectiveness when synchronization opportunities were sparse. Participants recommended academy-vessel coordination establishing clear expectations that m-learning engagement would occur primarily during port calls when reliable wifi is typically available, rather than attempting continuous mid-voyage access over expensive, slow satellite connections that create frustration and limit platform functionality.

#### 4. DISCUSSION

The findings provide robust empirical evidence that mobile learning applications significantly improve academy-to-ship training continuity, generating 17.6 percent composite competency development gains and 32.4 percent professional confidence improvements relative to traditional sea service training approaches. These effect sizes ( $d = 0.88$  and  $0.96$  respectively) substantially exceed typical educational technology intervention impacts documented in meta-analyses of digital learning effectiveness, where average effect sizes cluster around  $d = 0.30-0.40$  [7]. This suggests m-learning addresses a particularly acute learning need in the maritime academy-ship transition context where knowledge retention, theory-practice transfer, and ongoing instructional support challenges are more severe than in typical educational settings where students remain in continuous contact with instructors and learning resources.

The particularly large shipboard operations integration gains (+31.7 percent,  $d = 1.12$ ) provide especially compelling evidence for m-learning's value, as this domain specifically assesses the knowledge synthesis and practical application capabilities that sea service training is designed to develop but that traditional approaches struggle to support systematically. The integration domain required cadets to combine navigation knowledge, machinery understanding, safety procedures, and operational judgment in realistic scenario-based assessments mirroring actual shipboard decision-making. M-learning's effectiveness in improving precisely this integration and application capacity—rather than merely boosting recall of isolated facts—confirms that the intervention facilitates the professional competency development that is maritime education's ultimate objective [13].

Mobile Learning Applications for On-Board Training Continuity: Bridging Academy-to-Ship Educational Transition Through Digital Technology (*Derma Watty Sihombing*)

The just-in-time knowledge access mechanism identified as the dominant cadet experience theme aligns strongly with situated learning theory emphasizing that knowledge is most effectively acquired and applied when learning occurs in authentic contexts proximate to application opportunities [9]. M-learning enables a form of "situated review" where cadets can refresh theoretical knowledge immediately before or after encountering the shipboard situations where that knowledge becomes professionally relevant, creating temporal contiguity between learning and application that traditional academy-then-ship sequencing cannot achieve. This temporal contiguity addresses the fundamental challenge of academy-ship bifurcation: academy instruction occurs months before shipboard application opportunities, creating knowledge retention deficits and context transfer difficulties, while shipboard experience lacks the structured instructional support to systematically connect practice to underlying theoretical principles [2].

The just-in-time access finding has important practical implications for m-learning content design. Rather than attempting to digitally reproduce comprehensive academy courses, optimal maritime m-learning content should prioritize brief, task-specific micro-modules directly aligned with common shipboard situations cadets will encounter during watchkeeping and operational duties. For example, instead of a general 2-hour navigation course covering all collision avoidance regulations, m-learning should provide focused 10-minute modules addressing specific traffic scenarios: "Overtaking situations in restricted visibility," "Traffic separation scheme navigation," "Crossing situations with multiple vessels." This modular granularity enables cadets to quickly access precisely the knowledge segment relevant to their immediate situation rather than searching through comprehensive content to locate applicable information [14].

The mentoring augmentation finding addresses important concerns that digital learning technologies might displace the human mentoring relationships essential for professional socialization and tacit knowledge transfer in practice-based professions like maritime operations [4]. Rather than replacement, the data demonstrate complementarity: m-learning handles knowledge transmission and skills practice that can be effectively delivered through digital platforms, while freeing human mentors to focus on judgment development, professional identity formation, ethical reasoning, and complex problem-solving that requires experienced practitioner guidance and cannot be automated. This human-digital division of labor optimizes both mentoring efficiency and depth, addressing the reality that ship officers have limited time available for cadet development amid operational responsibilities [16].

The complementarity finding suggests that optimal implementation should explicitly integrate m-learning with structured shipboard mentoring protocols rather than treating them as separate training components. For example, mentoring schedules could be structured with alternating cycles where cadets complete designated m-learning modules preparing baseline knowledge, followed by mentoring sessions where officers guide application of that knowledge to operational scenarios, professional judgment development, and situational problem-solving. This structured integration ensures m-learning preparation actually enhances mentoring quality rather than merely adding parallel activity that cadets and officers struggle to coordinate [11].

The learning continuity visibility mechanism represents an important and perhaps underappreciated benefit of digital learning platforms. Traditional paper training record books provide academy faculty essentially no visibility into cadets' shipboard learning progression until physical return to academy months after sea service completion, at which point intervention opportunities for cadets who struggled have passed. Platform analytics and digital communication enable ongoing faculty monitoring and proactive support when usage patterns or question content reveal comprehension difficulties or engagement problems. This transforms academy instructors' role from passive record reviewers to active remote mentors who can provide guidance throughout sea service rather than only during academy periods [21].

However, the visibility benefit introduces important privacy and autonomy considerations requiring careful policy development. While academy faculty monitoring can enable beneficial support, excessive surveillance could undermine cadets' professional development autonomy and create anxiety about constant evaluation. Clear policies should specify what usage data faculty can access (aggregate engagement metrics yes, detailed content choices possibly not), when and why instructors will intervene (only when analytics suggest serious problems, not for minor variations in usage patterns), and how monitoring serves developmental support rather than punitive evaluation [12].

The connectivity constraint documented in FGD discussions and usage analytics introduces important implementation caveats. M-learning effectiveness demonstrated in this study may not generalize uniformly to vessels with severely limited internet access or trade routes with infrequent port calls providing synchronization opportunities. Future platform development should prioritize several technical strategies for managing connectivity constraints. First, maximize offline functionality by caching extensive content locally rather than streaming, design asynchronous interaction modes that gracefully handle delayed message delivery, and minimize data transmission requirements when connectivity is available. Second, develop intelligent

synchronization protocols that prioritize essential content and messages when bandwidth is limited rather than attempting comprehensive updates. Third, provide clear user interface feedback about offline status and what functionality remains available without connection to manage user expectations [8].

The dose-response relationship between usage intensity and learning outcomes (high users achieving 14.6 percentage points higher scores than low users) suggests that merely providing platform access is insufficient—sustainable engagement is essential for realizing m-learning benefits. This finding highlights the importance of motivational design, usability optimization, and institutional support structures that encourage consistent usage throughout sea service periods [15]. Specific strategies might include gamification elements that make engagement intrinsically rewarding, academy policies that explicitly allocate time for m-learning in cadet sea service expectations, ship officer encouragement and integration of platform usage into mentoring discussions, and visible progress tracking that gives cadets clear feedback on their development trajectory.

The study's quasi-experimental design—while substantially more rigorous than most maritime education technology research—introduces limitations requiring acknowledgment. Absence of random assignment means selection bias could confound results if intervention and control groups differed systematically beyond the matching variables controlled. Temporal differences between groups (control completing sea service in 2022, intervention in 2023) introduce potential history effects if other training changes occurred between periods. Future research should pursue randomized controlled trials where feasible, though practical and ethical constraints of denying potentially beneficial resources to control group cadets make such designs challenging in maritime education contexts [18].

## 5. CONCLUSION

This study demonstrates that mobile learning applications significantly improve competency development (+17.6 percent composite scores) and professional confidence (+32.4 percent self-efficacy) during academy-to-ship training transitions, with largest gains in theory-to-practice knowledge transfer and shipboard operations integration (+31.7 percent). Just-in-time knowledge access enabling situated review when learning relevance is highest, mentoring augmentation freeing officers to focus on judgment rather than remedial knowledge transmission, and learning continuity visibility enabling proactive academy instructor support emerge as primary mechanisms through which m-learning enhances sea service educational outcomes. However, effective implementation requires careful attention to connectivity constraints through robust offline functionality, integration with shipboard mentoring structures through coordinated protocols, and sustained engagement strategies including motivational design and institutional support. The M-Learning Continuity Framework proposed by this study—incorporating competency-based micro-learning modules aligned with shipboard tasks, offline-first platform architecture with periodic synchronization, structured mentoring integration protocols, academy-vessel communication channels for remote instructor support, and digital training records enabling learning progression visibility—provides maritime education institutions with evidence-grounded guidance for deploying mobile learning solutions that bridge the academy-ship training gap and enhance the professional development effectiveness of mandatory sea service periods.

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