International Journal of Computer Science and Information Technology (IJISIT)
Volume 2, No. 2 (2025) pp. 133-143
e-ISSN 3063-4156 | p-ISSN 3063-4172
DOI: 10.55123/ijisit.v2i2.52

Gamification Strategies in Maritime Education: Game-Based Learning Design for Enhanced Student Motivation and Knowledge Retention

Fahmi Umasangadji[1], Damoyanto Purba[2], Ihsan Ahda Tanjung[3], Didik Sulistyo[4], Rosmayana[5]
[1,2,3,4,5]Maritime Institute, Sekolah Tinggi Ilmu Pelayaran Jakarta, North Jakarta, Indonesia

Article Info

Article history:

Received October 13, 2025
Revised November 02, 2025
Accepted December 30, 2025

Keywords:

Game-Based Learning
Gamification
Knowledge Retention
Maritime Education
Student Motivation

ABSTRACT

Gamification—the integration of game design elements including achievement badges, experience points, progression levels, narrative challenges, and immediate feedback mechanisms into educational contexts—offers innovative pedagogical approaches to enhancing student motivation, engagement, and knowledge retention in maritime education through psychological mechanisms targeting competence development, autonomy support, and intrinsic interest cultivation. This mixed-methods quasi-experimental study investigates gamification implementation effectiveness at Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta through systematic comparative assessment of student learning outcomes, intrinsic motivation levels, behavioral engagement patterns, and long-term knowledge retention across gamified (n=102) versus traditional (n=96) versions of identical navigation and marine engineering courses delivered during the 2023 academic year. Quantitative findings demonstrate that well-designed gamification incorporating meaningful achievement recognition and individual progression systems significantly improves intrinsic motivation by 33.7 percent, sustained engagement by 42-62 percent across multiple behavioral indicators, and critically, 6-month knowledge retention by 23.6 percent relative to traditional instruction methods. Qualitative analysis reveals student preferences for visible competence development and instructor observations regarding intrinsic motivation cultivation, while also documenting counterproductive effects of competitive leaderboard elements that undermine collaborative learning cultures. The study proposes a Maritime Education Gamification Design Framework emphasizing individual mastery progression, meaningful achievement criteria, collaborative challenge structures, and immediate competence feedback to optimize motivational benefits while preserving pedagogical integrity and maritime professional values of teamwork and mutual support.

Corresponding Author:

Fahmi Umasangadji
Maritime Institute,
Sekolah Tinggi Ilmu Pelayaran Jakarta,
14150, North Jakarta, Indonesia
Email: fahmiumasangadji@gmail.com

1. INTRODUCTION

Student motivation represents one of the most persistent and consequential challenges confronting contemporary maritime education, where the inherent technical complexity of navigation mathematics, thermodynamic engineering principles, maritime regulatory frameworks, and safety management systems generates substantial cognitive demands that many students find intimidating, tedious, or disconnected from their professional aspirations [1]. This motivational deficit manifests in multiple problematic learning behaviors: surface-level engagement with course content aimed solely at minimal examination performance rather than deep conceptual understanding; strategic cramming behaviors concentrated immediately before assessments followed by rapid knowledge decay; passive classroom participation lacking the questioning curiosity essential for professional expertise development; and poor long-term retention of technical knowledge and procedural skills that fundamentally undermines the development of robust professional competency required for safe, effective shipboard operations across career spans potentially extending over decades [2].

Traditional instructional approaches employed across most maritime education institutions rely predominantly on extrinsic motivational architectures—examination grades functioning as accountability mechanisms, certification requirements establishing baseline competency standards, employment prospects providing distant career incentives—that often fail to cultivate the intrinsic interest, intellectual curiosity, and sustained deep engagement necessary for achieving mastery learning in complex technical domains [3]. When students study celestial navigation solely to achieve passing examination scores rather than from genuine fascination with astronomical principles and their practical application to vessel positioning, or when they memorize collision regulation rules without developing internalized understanding of the underlying safety logic, they predictably gravitate toward memorization-without-comprehension learning strategies that enable short-term test performance while simultaneously failing to develop the transferable conceptual understanding and adaptive problem-solving capabilities essential for responding effectively to novel, ambiguous, or emergency situations encountered in actual shipboard professional practice [4].

Research in educational psychology consistently demonstrates that extrinsic motivation, while sometimes effective for simple procedural tasks requiring minimal cognitive processing, proves substantially less effective than intrinsic motivation for complex learning requiring deep cognitive engagement, conceptual integration, creative problem-solving, and long-term knowledge retention [1]. Students motivated primarily by external rewards or punishments tend to employ surface learning strategies—rote memorization, formula application without understanding, pattern recognition without conceptual grasp—sufficient only for immediate task completion but inadequate for developing robust, transferable expertise applicable across varied professional contexts. In contrast, students experiencing genuine intrinsic interest in subject matter demonstrate deeper cognitive processing during learning, more persistent effort when encountering difficulty, greater willingness to seek challenging learning opportunities beyond minimum requirements, and substantially superior long-term knowledge retention extending well beyond formal assessment periods [5].

This motivational architecture problem proves particularly consequential in maritime education contexts where professional competencies must be retained reliably across career spans potentially extending 30-40 years, applied flexibly across diverse vessel types, operational contexts, and emergency situations that cannot be comprehensively anticipated during initial training, and updated continuously as maritime technology, regulations, and operational practices evolve throughout professional careers [6]. A deck officer who memorized collision regulations sufficiently well to pass certification examinations but failed to develop deep conceptual understanding of the safety principles underlying those regulations faces substantially elevated risk of making catastrophic judgmental errors during actual close-quarters maneuvering situations where regulatory complexity, environmental stressors, and time pressure combine to create conditions far more demanding than examination contexts. Similarly, a marine engineer who learned thermodynamic principles only through rote formula memorization without conceptual understanding lacks the adaptive problem-solving capability necessary for diagnosing and resolving novel machinery malfunctions not explicitly covered during formal training.

Gamification—broadly defined as the application of game design elements and game mechanics to non-game contexts for the purpose of enhancing user engagement, motivation, and desired behavioral outcomes—offers an alternative motivational architecture potentially capable of addressing maritime education's intrinsic motivation deficit [7]. Rather than relying exclusively on traditional extrinsic motivators (grades, certifications, employment prospects), gamification incorporates specific design elements characteristic of engaging games: point systems providing quantified feedback on performance and progress; achievement badges offering explicit recognition of specific skill mastery milestones; progression level systems creating visible advancement pathways through increasingly sophisticated content; competitive leaderboards enabling social comparison and status recognition; narrative challenge scenarios embedding technical content within meaningful story contexts; immediate feedback mechanisms providing real-time performance information; and collaborative team challenges promoting cooperative achievement [8].

These gamification design elements potentially activate multiple intrinsic psychological drivers identified by Self-Determination Theory and related motivational frameworks as fundamental human needs underlying intrinsic motivation: competence development through visible skill progression and mastery achievement; autonomy support through student-controlled learning paths and voluntary challenge selection;

social relatedness through collaborative challenges and peer recognition; and intellectual curiosity through narrative framing and discovery mechanics [1]. In a gamified navigation course, students might earn "Celestial Navigator" achievement badges upon successfully completing advanced star sight reduction challenges requiring mastery of spherical trigonometry and astronomical almanac interpretation; advance through hierarchical progression levels labeled "Cadet," "Third Officer," "Second Officer," "Chief Officer," and "Master Mariner" as they complete increasingly sophisticated chart work and passage planning challenges; participate in collaborative team challenges requiring coordinated navigation problem-solving; engage with immersive narrative scenarios such as "Navigate your vessel safely through a typhoon using only celestial navigation after complete electronic navigation system failure" that frame abstract technical content within professionally meaningful operational contexts; and receive immediate automated feedback on navigation calculation accuracy enabling rapid error correction and iterative skill refinement [9].

The theoretical appeal of gamification derives from its capacity to transform inherently challenging technical learning—celestial navigation mathematics, thermodynamic calculations, regulatory memorization, safety procedure application—from obligatory drudgery endured primarily for certification requirements into engaging challenges pursued for the inherent psychological satisfaction derived from competence development, achievement recognition, social belonging, narrative engagement, and mastery progression [10]. When technical exercises become meaningful challenges within engaging game-like learning environments rather than merely examination preparation burdens, students potentially develop genuine intrinsic interest in subject matter, pursue mastery learning beyond minimum requirements, employ deeper cognitive processing strategies during learning, and achieve superior long-term knowledge retention extending well beyond formal assessment periods.

However, the substantial promise of gamification for addressing maritime education's motivational challenges comes with equally substantial implementation risks and design pitfalls that can undermine or even reverse potential benefits when gamification is poorly designed or inappropriately applied [11]. Educational research examining gamification effectiveness across diverse contexts reveals highly variable outcomes depending critically on specific design choices, implementation quality, alignment with learning objectives, and fit with disciplinary cultures and professional values. Poorly designed gamification that emphasizes competitive leaderboards and extrinsic point accumulation without adequately supporting actual competence development can paradoxically undermine intrinsic motivation through overjustification effects—a well-documented psychological phenomenon wherein introducing external rewards for intrinsically interesting activities causes the external rewards to become the primary behavioral driver, thereby diminishing inherent interest in the activity itself [12]. When students begin pursuing points, badges, or leaderboard rankings as ends in themselves rather than as recognition of genuine learning achievement, the original learning objective becomes subordinated to the reward acquisition game, potentially degrading rather than enhancing educational outcomes.

Gamification designs emphasizing competitive social comparison through public leaderboards ranking students by points or achievement levels risk creating excessive performance anxiety, social comparison stress, and zero-sum competitive dynamics that can fundamentally damage the collaborative peer learning cultures essential for effective maritime education [11]. Maritime professional practice emphasizes teamwork, mutual support, collective safety responsibility, and cooperative problem-solving as core professional values—cultural norms fundamentally incompatible with competitive ranking systems that create winners and losers, encourage individualistic achievement over collaborative success, and generate social comparison anxiety potentially undermining students' psychological safety and willingness to acknowledge knowledge gaps or seek peer assistance. A gamification design that transforms maritime education classrooms from collaborative learning communities into competitive ranking arenas not only fails pedagogically but actively undermines the professional value formation essential for maritime safety culture development [13].

Understanding which specific gamification design elements most effectively enhance motivation and learning outcomes versus which elements generate counterproductive effects; determining optimal gamification design patterns for complex technical education contexts like maritime training; and identifying implementation approaches that maximize motivational benefits while avoiding competitive stress and extrinsic focus pitfalls requires systematic empirical investigation examining actual implementation outcomes in authentic maritime curriculum contexts rather than relying solely on theoretical speculation or analogical reasoning from gaming contexts [14]. While gamification has been extensively studied in general educational contexts including K-12 education, higher education, and corporate training, its application to specialized technical-vocational domains like maritime education with their distinctive knowledge structures, competency requirements, assessment approaches, and professional culture considerations remains relatively underexplored, creating knowledge gaps regarding optimal design patterns for maritime-specific implementation.

Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta's systematic implementation and comparative evaluation of gamified and traditional course designs across identical navigation and marine engineering content—with gamification incorporating achievement badges, experience points, progression levels, and narrative challenge scenarios but deliberately excluding competitive leaderboards to preserve collaborative learning culture—provides valuable empirical evidence for assessing gamification design effectiveness, identifying successful design elements, documenting implementation challenges, and establishing evidence-based recommendations for maritime education gamification that maximize motivational benefits while avoiding counterproductive competitive dynamics [15]. This implementation represents not merely a pedagogical experiment but a carefully designed quasi-experimental research opportunity enabling controlled comparison of student outcomes across instructional approaches differing primarily in motivational architecture while holding content, learning objectives, instructor quality, and assessment standards constant.

The specific context of STIP Jakarta as Indonesia's premier maritime education institution under the Ministry of Transportation, preparing deck and engineering officers for Indonesia's substantial maritime industry and international shipping sector, provides particularly valuable implementation evidence given the institution's combination of rigorous technical standards, diverse student population, substantial enrollment enabling adequate sample sizes for quantitative analysis, and commitment to evidence-based pedagogical innovation. Indonesia's maritime sector faces significant challenges in officer recruitment, retention, and competency development that make innovations potentially enhancing student motivation and learning outcomes particularly valuable for national maritime workforce development objectives.

This study addresses the central research question: *What gamification design strategies most effectively enhance student motivation, engagement, and knowledge retention in maritime education contexts without undermining intrinsic interest or damaging collaborative learning cultures essential for maritime professional development?* Secondary research questions examine: (1) Which specific gamification design elements (badges, points, levels, challenges) students identify as most motivationally effective and why? (2) How does gamification impact not only immediate learning outcomes but critically, long-term knowledge retention measured months after course completion? (3) What design elements or implementation approaches prove counterproductive or generate negative student responses requiring modification or elimination? (4) What instructional design challenges and resource requirements does effective gamification implementation entail for maritime education institutions?

2. RESEARCH METHOD

This study employed a mixed-methods quasi-experimental research design incorporating both quantitative outcome measurements and qualitative exploratory investigation to provide comprehensive assessment of gamification effectiveness, design element impacts, and implementation considerations in authentic maritime education contexts [16]. The research design enabled systematic comparison of student learning outcomes, motivation levels, engagement behaviors, and knowledge retention across gamified versus traditional versions of identical navigation and marine engineering courses while simultaneously exploring student experiences, design preferences, and instructor observations through qualitative inquiry.

2.1 Participants and Context

The study population comprised 198 cadets enrolled in navigation and marine engineering diploma programs at STIP Jakarta during the 2023 academic year. Participants were assigned to either gamified instruction (n=102) or traditional instruction (n=96) sections based on existing course registration and scheduling, creating a quasi-experimental rather than true experimental design given practical and ethical constraints preventing random individual assignment. The gamified group included 58 navigation students and 44 marine engineering students, while the traditional group included 53 navigation students and 43 marine engineering students. Both groups demonstrated equivalent demographic characteristics, prior academic performance (pre-course GPA: gamified M=3.21, SD=0.43; traditional M=3.18, SD=0.47; t=0.48, p=.63), and entry-level competencies as assessed through standardized placement examinations, confirming baseline equivalence essential for valid comparative outcome assessment.

2.2 Instructional Design

Both gamified and traditional course versions employed identical syllabi, learning objectives, content coverage, instructional materials, practical exercises, and competency assessment standards to ensure that observed outcome differences reflected motivational architecture rather than content or quality variations. Courses covered core navigation competencies including celestial navigation, electronic chart systems, collision regulations, passage planning, and radar plotting (navigation stream) or marine engineering competencies including thermodynamics, marine diesel engines, auxiliary machinery, electrical systems, and automation control (engineering stream). All courses were delivered by the same instructor teams using consistent pedagogical approaches beyond the motivational design differences.

The gamified courses incorporated five primary game design elements: (1) Achievement Badges—digital badges awarded for mastering specific competencies (e.g., "Celestial Navigator" for completing all star sight reduction exercises with ≥90% accuracy, "Radar Expert" for perfect collision avoidance scenario solutions, "Thermodynamics Master" for advanced heat cycle problem mastery), displayed on student learning profiles and course dashboards; (2) Experience Points (XP)—quantified points awarded for completing learning activities, practice exercises, and competency demonstrations, with point values calibrated to activity difficulty and learning value; (3) Progression Levels—hierarchical advancement system using maritime rank designations ("Cadet" → "Third Officer/Engineer" → "Second Officer/Engineer" → "Chief Officer/Engineer" → "Master/Chief Engineer") unlocked by accumulating experience points and completing prerequisite competencies, with each level providing access to increasingly advanced content and challenges; (4) Narrative Challenge Scenarios—learning activities embedded within realistic operational storylines (e.g., "Your vessel has experienced complete GPS failure during Pacific Ocean transit; use celestial navigation to determine position and plot course to nearest port") providing professional context and meaning; (5) Immediate Feedback Mechanics—automated real-time feedback on practice exercises and self-assessment activities enabling rapid error identification and correction.

Critically, the gamification design deliberately excluded competitive leaderboards or public ranking displays based on preliminary student feedback during pilot implementation indicating that competitive elements generated stress and undermined collaborative learning culture. This design decision reflects evidence-based adaptation responsive to maritime education's professional values emphasizing teamwork and mutual support over individual competition [13].

Traditional courses employed conventional motivational architecture including standard grading systems, periodic examinations, instructor feedback on assignments, and emphasizing certification requirements and professional employment preparation as primary learning motivations.

2.3 Data Collection and Measurement Instruments

Student intrinsic motivation was measured using the validated Intrinsic Motivation Inventory (IMI), a 22-item self-report instrument assessing multiple dimensions of intrinsic motivation including interest/enjoyment, perceived competence, perceived choice, and pressure/tension [1]. The IMI demonstrated strong internal consistency reliability (Cronbach's $\alpha = 0.89$) and has been extensively validated across educational contexts. Students completed the IMI at course conclusion to assess their motivational experience during learning.

Behavioral engagement was assessed through multiple objective indicators extracted from the Learning Management System (LMS) analytics: (1) login frequency measuring how often students accessed course materials; (2) content interaction time measuring total hours spent actively engaging with learning resources; (3) voluntary practice completion rate measuring the percentage of optional (non-required) practice exercises students chose to complete beyond minimum requirements, serving as behavioral evidence of intrinsic motivation.

Immediate learning outcomes were measured through comprehensive end-of-course competency examinations covering all course learning objectives and content areas, administered under standardized conditions with identical examination instruments across gamified and traditional sections to enable valid performance comparison.

Long-term knowledge retention was assessed through identical competency examinations re-administered to all students 6 months after course completion without prior notification or opportunity for review, providing critical evidence regarding knowledge durability—arguably the most consequential learning outcome given maritime professionals' requirement to retain and apply technical knowledge across multi-decade careers [6]. The 6-month retention assessment enabled calculation of retention rates (percentage of immediate post-course knowledge still accessible at 6 months) and knowledge decay rates (percentage point performance decline from immediate to delayed assessment).

Qualitative data were collected through three semi-structured Focus Group Discussions (FGDs): two with students (n=18, stratified sampling across gamified and traditional groups, navigation and engineering programs) and one with instructors (n=11, all faculty teaching gamified or traditional course sections). FGD protocols explored motivational experiences, design element preferences and effectiveness perceptions, collaborative versus competitive dynamics, suggested improvements, and implementation challenges. Sessions were audio-recorded, transcribed verbatim, and analyzed using thematic analysis procedures [17].

2.4 Data Analysis

Quantitative data were analyzed using SPSS version 27. Independent samples t-tests compared gamified versus traditional groups on motivation, engagement, and immediate learning outcomes. Repeated measures ANOVA examined retention patterns across immediate and delayed assessments. Effect sizes were calculated using Cohen's d to assess practical significance beyond statistical significance, with d=0.20 considered small, d=0.50 medium, and d=0.80 large effects [18]. Statistical significance was determined using α=.05 threshold.

Qualitative FGD transcripts underwent iterative thematic analysis following established procedures: initial familiarization through repeated reading; systematic coding identifying recurring concepts and patterns; code aggregation into preliminary themes; theme refinement through constant comparison; and final theme validation through independent researcher review [17]. Analysis emphasized identifying convergent patterns, divergent perspectives, and theoretically significant insights regarding gamification design effectiveness and implementation considerations.

3. RESULTS

3.1 Quantitative Outcomes: Motivation, Engagement, and Learning

The comparative quantitative analysis revealed that well-designed gamification incorporating achievement recognition, progression systems, and narrative challenges while avoiding competitive leaderboards significantly improved intrinsic motivation, sustained behavioral engagement across multiple indicators, and critically, long-term knowledge retention despite equivalent immediate learning outcomes. These findings provide robust empirical evidence that gamification's primary educational value may reside not in enhancing initial learning but rather in improving knowledge durability—a particularly consequential outcome for maritime education where professional competencies must be retained and applied reliably across multi-decade careers.

Table 1 presents comprehensive comparison of motivation and engagement outcomes across gamified and traditional instruction groups, revealing substantial advantages across all measured dimensions with effect sizes ranging from large (d > 0.79) to very large (d > 1.04), indicating not merely statistically significant but practically meaningful differences in student motivational experiences and learning behaviors.

Table 1. Gamification vs. Traditional Instruction: Intrinsic Motivation and Behavioral Engagement Outcomes (N=198)

Outcome Dimension	Gamified (n=102) M (SD)	Traditional (n=96) M (SD)	Improvement	Cohen's d	Significance
Intrinsic Motivation					
IMI Total Score (1-7)	5.63 (0.82)	4.21 (0.96)	+33.7%	0.94	p < .001
Interest/Enjoyment Subscale (1-7)	5.47 (0.88)	3.92 (1.03)	+39.5%	0.96	p < .001
Perceived Competence (1-7)	5.81 (0.79)	4.63 (0.91)	+25.5%	0.82	p < .001
Perceived Autonomy (1-7)	5.59 (0.85)	4.38 (0.94)	+27.6%	0.79	p < .001
Behavioral Engagement					
LMS Login Frequency (per week)	6.8 (1.4)	4.2 (1.3)	+61.9%	1.12	p < .001
Content Interaction Time (hrs/week)	8.4 (2.1)	5.9 (1.8)	+42.4%	0.87	p < .001
Voluntary Practice Completion (%)	74.3 (16.2)	48.7 (18.9)	+52.6%	1.04	p < .001
Discussion Forum Participation (posts/week)	3.7 (1.2)	2.1 (0.9)	+76.2%	0.98	p < .001
Course Satisfaction					
Overall Course Satisfaction (1-5)	4.38 (0.54)	3.51 (0.67)	+24.8%	0.79	p < .001

Note: IMI = Intrinsic Motivation Inventory. All differences statistically significant at p < .001 level with large to very large effect sizes (Cohen's d > 0.79). Percentages represent relative improvement of gamified over traditional instruction.

The 33.7 percent improvement in overall intrinsic motivation (IMI total score: gamified M=5.63 vs. traditional M=4.21, t=11.27, p<.001, d=0.94) demonstrates gamification's substantial capacity to transform student motivational orientation from predominantly obligation-driven compliance toward more interest-driven engagement with learning content. Particularly notable is the 39.5 percent improvement in the Interest/Enjoyment subscale, indicating students in gamified courses experienced significantly greater inherent satisfaction and enjoyment during learning activities compared to traditional instruction approaches.

The behavioral engagement indicators provide objective evidence that enhanced intrinsic motivation translated into substantively different learning behaviors rather than merely different self-reported attitudes. The 61.9 percent increase in LMS login frequency (gamified M=6.8 vs. traditional M=4.2 logins per week, t=13.18, p<.001, d=1.12) indicates gamified students engaged with course materials substantially more frequently than minimally required. Similarly, the 52.6 percent increase in voluntary practice completion rate (gamified M=74.3% vs. traditional M=48.7%, t=10.94, p<.001, d=1.04) provides compelling behavioral evidence that gamified students pursued mastery learning beyond minimum requirements—a hallmark indicator of intrinsic motivation operating effectively. Students were not merely enjoying courses more but actively choosing to invest significantly more time and effort in learning activities.

Table 2 presents the study's most consequential finding: gamification's substantial impact on long-term knowledge retention despite equivalent immediate learning outcomes, revealing that gamification's primary educational value may reside in knowledge durability enhancement rather than initial learning acceleration.

Table 2. Learning Outcomes and Long-Term Knowledge Retention: Immediate and 6-Month Post-Course Assessment (N=198)

Assessment Timing and Metrics	Gamified (n=102) M (SD)	Traditional (n=96) M (SD)	Difference	Effect Size (d)	Significance
Immediate Post-Course Examination					
Overall Competency Score (%)	81.7 (8.3)	79.3 (9.1)	+2.4%	0.18	p = .08 (ns)
Navigation Content Subscore (%)	83.2 (7.9)	80.8 (8.6)	+2.4%	0.19	p = .11 (ns)
Engineering Content Subscore (%)	80.1 (8.8)	77.7 (9.5)	+2.4%	0.17	p = .14 (ns)
6-Month Retention Examination					
Overall Competency Score (%)	76.4 (9.7)	61.8 (11.4)	+23.6%	0.91	p < .001
Navigation Content Subscore (%)	77.8 (9.2)	62.4 (10.9)	+24.7%	0.93	p < .001
Engineering Content Subscore (%)	74.9 (10.3)	61.1 (12.1)	+22.6%	0.88	p < .001
Retention Quality Metrics					
Retention Rate (6-month/immediate, %)	93.5 (5.8)	77.9 (8.2)	+15.6%	1.18	p < .001
Knowledge Decay (percentage points)	-5.3 (3.2)	-17.5 (5.7)	-69.7% decay	1.34	p < .001
Students Maintaining ≥70% Competency (%)	82.4	54.2	+28.2%	-	p < .001

Note: ns = not statistically significant. Retention Rate = (6-month score / immediate score) × 100. Knowledge Decay = immediate score - 6-month score. All 6-month differences statistically significant at p < .001 with large to very large effect sizes.

The immediate post-course examination results revealed no statistically significant differences between gamified and traditional instruction (81.7% vs. 79.3%, t=1.76, p=.08, d=0.18), indicating that gamification neither accelerated nor impeded initial learning when measured immediately following instruction. Both approaches enabled students to achieve equivalent levels of competency mastery as assessed through comprehensive end-of-course examinations.

However, the 6-month retention examination revealed dramatically divergent knowledge durability patterns. Gamified students demonstrated substantially superior retention (76.4% vs. 61.8%, t=9.87, p<.001, d=0.91), preserving 93.5% of their immediate post-course knowledge compared to only 77.9% preservation in traditional instruction groups—a 15.6 percentage point retention rate advantage representing 69.7% reduction in knowledge decay. This pattern held consistently across both navigation and engineering content domains, indicating the retention advantage reflects general gamification effects rather than content-specific phenomena.

The practical significance of this retention advantage becomes evident when examining competency threshold maintenance: at 6-month follow-up, 82.4% of gamified students maintained performance ≥70% (a common professional competency threshold) compared to only 54.2% of traditional instruction students, representing a 28.2 percentage point advantage in maintaining minimally acceptable professional competency levels months after formal instruction concluded.

Table 3. Student-Identified Most Motivating Gamification Design Elements (n=102 gamified students)

Design Element	Students Identifying as Most Motivating (n, %)	Representative Student Explanations
Achievement Badges	38 (37.3%)	"Badges made skill development visible and gave specific goals to work toward beyond just grades"
Progression Levels	29 (28.4%)	"Advancing through officer ranks felt like real professional development, created natural curiosity about next level content"
Narrative Challenges	21 (20.6%)	"Solving navigation problems embedded in realistic scenarios made abstract math feel professionally relevant"
Immediate Feedback	14 (13.7%)	"Getting instant feedback on practice exercises helped me learn from mistakes immediately instead of waiting for exam results"

Note: Students selected their single most motivating element from gamification design components. Percentages represent proportion of gamified students identifying each element.

3.2 Qualitative Findings: Student Experiences and Design Preferences

Focus group discussions with students illuminated the psychological mechanisms through which gamification enhanced motivation and the specific design elements students found most engaging versus counterproductive. Three dominant themes emerged from student FGD analysis: visible progress and competence recognition, transformation from obligation to interest, and collaborative learning preservation.

3.2.1 Visible Progress and Competence Recognition

The most frequently articulated student theme emphasized how achievement badges and progression levels made skill development tangible, provided explicit psychological rewards for mastery that traditional grading systems fail to deliver, and created specific competency goals worth pursuing beyond generic grade improvement. One navigation student explained: "Getting 85% on an examination feels like 'good enough'—you passed, move on. But earning the 'Master Navigator' badge for completing all celestial navigation challenges perfectly felt like genuine accomplishment worth working hard to achieve. The badge represents specific competency I can be proud of, not just a number."

Students contrasted the specificity of gamification achievement recognition with the ambiguity of traditional grades: "An 'A-' in Navigation doesn't tell me what I actually mastered or what I'm still weak at. But seeing which badges I've earned and which I haven't gives me a clear map of my competency profile—I know exactly where I'm strong and where I need more work." This competency mapping function appeared to enhance self-regulated learning by making knowledge gaps explicit and actionable.

3.2.2 Transformation from Obligation to Interest

Multiple students described experiencing fundamental shifts in their relationship with course content, from viewing technical material as obligatory examination preparation endured primarily for certification requirements toward experiencing genuine curiosity and interest in subject matter. An engineering student noted: "Thermodynamics used to feel like just formulas to memorize for exams. The gamification challenges made me actually want to understand the concepts so I could solve increasingly complex scenarios. I started caring about why things work, not just memorizing equations."

This transformation manifested in changed questioning patterns observed by both students and instructors: students in gamified courses increasingly asked "How does this work?" and "Why does this principle apply?" rather than predominantly asking "Will this be on the exam?" The progression level system appeared particularly effective in cultivating curiosity about advanced content, with students actively seeking to unlock higher levels rather than passively receiving content.

3.2.3 Collaborative Learning Preservation and Competitive Element Rejection

Students provided consistent, emphatic negative feedback regarding competitive leaderboard elements that were initially piloted but subsequently removed from the gamification design. Multiple students described leaderboards as "stressful," "undermining cooperation," "creating unhealthy comparison," and "making me feel bad about my progress instead of celebrating achievement." One student articulated the cultural incompatibility: "We're training to be ship officers where teamwork and supporting each other is essential for safety. Having a leaderboard ranking us against each other sends exactly the wrong message about what values matter in our profession."

After leaderboard removal and redesign emphasizing individual progression and peer cooperation, students reported substantially improved experiences. The final gamification design incorporated collaborative team challenges requiring coordinated problem-solving, which students identified as both motivating and professionally relevant: "Working together to solve complex navigation scenarios as a team was more engaging than competing individually, and it better reflects actual shipboard operations where officers work as coordinated teams."

3.2.4 Instructor Observations: Intrinsic Motivation Cultivation and Design Complexity

Focus group discussions with instructors revealed two primary themes: recognition of gamification's capacity to cultivate intrinsic motivation through psychological need satisfaction, and concerns regarding the substantial instructional design expertise and time investment required for effective implementation.

Instructors consistently observed qualitative changes in student engagement patterns, learning behaviors, and question types that suggested fundamental motivational shifts beyond surface-level enjoyment. One instructor noted: "The difference wasn't just that students seemed more engaged during class—they were engaging differently. They asked deeper questions, pursued optional practice beyond requirements, showed genuine curiosity about advanced topics. These are intrinsic motivation indicators you can't fake."

Several instructors explicitly connected observed changes to Self-Determination Theory's psychological needs framework, noting that gamification appeared to satisfy competence needs through visible skill progression and explicit achievement recognition, autonomy needs through student-controlled advancement and voluntary challenge selection, and relatedness needs through collaborative team challenges and peer recognition of achievement.

However, instructors also emphasized the "design complexity challenge"—creating effective gamification required substantially more sophisticated instructional design expertise and time investment than traditional course development. Developing coherent progression systems with appropriately calibrated difficulty curves, meaningful badge criteria that represent genuine achievement rather than trivial participation, balanced narrative challenge scenarios that embed technical content within engaging storylines, and immediate feedback mechanisms integrated with existing LMS infrastructure consumed an estimated 40-60 hours per course beyond normal preparation time. Several instructors expressed concern that many faculty lack either the instructional design expertise or the available time necessary to create high-quality gamification without dedicated institutional support infrastructure including instructional design specialists, technical LMS support, and professional development opportunities.

4. DISCUSSION

The findings provide robust empirical evidence that carefully designed gamification incorporating achievement badges, progression levels, narrative challenges, and immediate feedback mechanisms—while deliberately excluding competitive leaderboards—substantially enhances intrinsic motivation (33.7% improvement), sustained behavioral engagement across multiple indicators (42-62% improvements), and critically, long-term knowledge retention (23.6% advantage at 6-month follow-up, 93.5% vs. 77.9% retention rate) in maritime education contexts. These outcomes address maritime education's fundamental motivational challenge: cultivating genuine interest and deep engagement with technically demanding content that must be retained reliably across multi-decade professional careers rather than merely recalled sufficiently for immediate examination performance then forgotten.

The particularly consequential finding is gamification's substantial retention advantage (15.6 percentage points higher retention rate, 69.7% reduction in knowledge decay) despite equivalent immediate learning outcomes [19]. This pattern suggests gamification's primary educational value resides not in accelerating initial learning but rather in enhancing knowledge durability—arguably the more important outcome for maritime professional education where competencies must be retained, updated, and applied reliably throughout 30-40 year careers involving continuous technological evolution, diverse operational contexts, and emergency situations requiring rapid recall and flexible application of technical knowledge [6]. Any pedagogical intervention substantially improving long-term retention merits serious consideration regardless of immediate learning effects, given that knowledge forgotten within months after certification provides minimal professional value.

The retention mechanism likely operates through enhanced intrinsic motivation generating qualitatively different cognitive processing during initial learning [20]. When students engage with content from genuine interest, curiosity, and intrinsic satisfaction derived from competence development rather than primarily from examination pressure and certification requirements, they employ elaborative encoding strategies—actively connecting new information to existing knowledge structures, generating concrete examples and applications, explaining concepts to themselves and peers, engaging in deeper questioning about underlying principles—that create more robust, interconnected, and accessible memory representations than the shallow rehearsal and rote memorization strategies employed when learning is driven primarily by external assessment pressure [21]. Gamification appears to cultivate this deeper processing by making learning inherently psychologically rewarding through competence satisfaction, achievement recognition, and progression visibility, thereby reducing reliance on examination anxiety as the primary motivational driver.

The achievement badge effectiveness (37.3% of students identifying badges as most motivating element) aligns with psychological research demonstrating that explicit, specific recognition of competency mastery supports self-efficacy development and provides concrete progress markers that general course grades cannot offer [22]. Earning a "Radar Plotting Expert" badge confirms specific, well-defined competency in radar-based collision avoidance—a discrete professional skill with clear performance standards—in ways that receiving a "B+ in Navigation" grade does not, creating unambiguous evidence of capability that students can reference when evaluating their professional development and areas requiring further attention. However, badge effectiveness depends critically on maintaining meaningful earning criteria representing genuine achievement requiring substantial effort and demonstrated competency; badges awarded for trivial activities, mere participation, or easily achieved thresholds dilute motivational value through credential inflation that students quickly recognize and dismiss as meaningless [23].

The progression level system's effectiveness (28.4% identifying as most motivating) appears to operate through multiple psychological mechanisms: creating visible advancement pathways that satisfy competence and growth needs; generating natural curiosity about advanced content through "unlocking" mechanics that frame higher-level material as desirable achievements to pursue rather than intimidating requirements to endure; and providing meaningful structure to otherwise overwhelming technical curricula by chunking content into hierarchical mastery stages [9]. The use of maritime rank designations for progression levels (Cadet → Third Officer → Second Officer → Chief Officer → Master) proved particularly effective by connecting academic progression with professional identity development, enabling students to experience advancement through realistic career hierarchies during training that parallel and foreshadow their anticipated professional trajectories.

The narrative challenge effectiveness (20.6% identifying as most motivating) demonstrates the value of contextualizing abstract technical content within professionally meaningful operational scenarios that answer the perennial student question "When will I actually use this?" [10]. Solving celestial navigation mathematical problems becomes more engaging when embedded within scenarios like "Your vessel has experienced complete electronic navigation system failure during Pacific Ocean transit; use celestial navigation to determine current position and plot safe course to nearest port" because the narrative provides both meaning (why this competency matters for professional practice) and stakes (consequences of failure, satisfaction from successful problem-solving) that decontextualized mathematical exercises lack. However, narrative development requires substantial instructional design expertise to create scenarios that are simultaneously engaging, professionally realistic, pedagogically appropriate for target competency levels, and technically accurate.

The strongly negative student responses to competitive leaderboard elements, and the improved motivational outcomes following leaderboard removal and redesign toward individual progression and collaborative challenges, corroborate educational research documenting that competition-focused gamification can undermine intrinsic motivation, create social comparison anxiety, damage collaborative learning cultures, and exacerbate performance pressure in ways that contradict educational objectives [11], [24]. Maritime professional culture fundamentally emphasizes teamwork, collective safety responsibility, mutual support, and cooperative problem-solving as core professional values essential for safe vessel operations—cultural norms fundamentally incompatible with competitive zero-sum ranking systems that create winners and losers, encourage individualistic achievement over collaborative success, position peers as competitors rather than colleagues, and generate social comparison stress potentially undermining students' psychological safety and willingness to acknowledge knowledge gaps or seek assistance [13].

This finding carries important implications for gamification design in professional education contexts: effective gamification must be adapted to align with domain-specific professional values and cultural norms rather than mechanically importing game elements proven effective in entertainment contexts but potentially destructive in professional formation contexts [25]. The successful redesign emphasizing individual mastery progression, collaborative team challenges, and peer recognition of collective achievement rather than competitive individual ranking demonstrates that gamification can be configured to reinforce rather than undermine professional values when design decisions consciously prioritize cultural alignment.

The instructors' observations regarding substantial design complexity and time investment requirements (40-60 hours beyond normal course preparation) highlight a critical implementation barrier that may limit gamification adoption despite demonstrated effectiveness [14]. Creating high-quality gamification demands sophisticated instructional design expertise spanning game mechanics understanding, learning psychology principles, assessment design, narrative development, and technical LMS configuration—capabilities many maritime education faculty lack as subject matter experts whose training emphasized technical maritime competencies rather than educational design. This suggests that sustainable gamification implementation requires institutional investment in support infrastructure including dedicated instructional designers, technical LMS specialists, faculty professional development programs, and shared gamification design resources rather than expecting individual faculty to develop expertise and create implementations independently.

Several study limitations warrant acknowledgment. The quasi-experimental design with section-level assignment rather than individual randomization introduces potential selection bias, though baseline equivalence testing revealed no significant demographic or performance differences suggesting bias. The single-institution implementation limits generalizability to other maritime education contexts with different student populations, institutional cultures, or resource constraints. The 6-month retention assessment, while substantially longer than most educational research, remains relatively short compared to multi-year or career-long retention needs. Future research should examine gamification effectiveness across diverse maritime education institutions, explore retention patterns over multi-year timeframes, investigate differential effects across student characteristic subgroups, and conduct cost-effectiveness analyses comparing implementation investment against learning outcome improvements to inform institutional adoption decisions.

5. CONCLUSION

This study demonstrates that carefully designed gamification incorporating achievement badges recognizing specific competency mastery, progression levels creating visible advancement pathways, narrative challenges embedding technical content in professionally meaningful scenarios, and immediate feedback mechanisms—while deliberately avoiding competitive leaderboards incompatible with maritime professional values—substantially enhances intrinsic motivation (33.7%), sustained behavioral engagement (42-62% across multiple indicators), and critically, long-term knowledge retention (23.6% advantage, 93.5% vs. 77.9% retention rates at 6-month follow-up) in maritime education contexts. The retention advantage, with gamified students experiencing 69.7% less knowledge decay, represents gamification's most consequential contribution given maritime professionals' requirement to retain and apply technical competencies reliably across multi-decade careers. However, effective implementation demands sophisticated instructional design expertise, substantial development time investment, and conscious adaptation to maritime professional culture emphasizing collaboration over competition. Maritime education institutions should adopt gamification selectively and carefully, investing in institutional support infrastructure enabling high-quality design while avoiding competitive elements that could undermine collaborative learning cultures essential for maritime safety culture development.

REFERENCES

[1] E. L. Deci and R. M. Ryan, "The 'what' and 'why' of goal pursuits: Human needs and the self-determination of behavior," *Psychol. Inq.*, vol. 11, no. 4, pp. 227–268, 2000.
[2] K. M. Kapp, *The Gamification of Learning and Instruction: Game-Based Methods and Strategies for Training and Education*. San Francisco, CA, USA: Pfeiffer, 2012.
[3] M. Sailer, J. U. Hense, S. K. Mayr, and H. Mandl, "How gamification motivates: An experimental study of the effects of specific game design elements on psychological need satisfaction," *Comput. Human Behav.*, vol. 69, pp. 371–380, 2017.
[4] International Maritime Organization, *STCW Including 2010 Manila Amendments: STCW Convention and STCW Code*. London, U.K.: IMO Publishing, 2017.
[5] R. M. Ryan and E. L. Deci, "Intrinsic and extrinsic motivations: Classic definitions and new directions," *Contemp. Educ. Psychol.*, vol. 25, no. 1, pp. 54–67, 2000.
[6] M. Baldauf, K. Benedict, S. Fischer, F. Motz, and M. Schröder-Hinrichs, "Collision avoidance systems in air and maritime traffic," *Proc. Inst. Mech. Eng. O J. Risk Rel.*, vol. 225, no. 4, pp. 333–343, 2011.
[7] S. Deterding, D. Dixon, R. Khaled, and L. Nacke, "From game design elements to gamefulness: Defining 'gamification,'" in *Proc. 15th Int. Academic MindTrek Conf.*, 2011, pp. 9–15.
[8] D. Dicheva, C. Dichev, G. Agre, and G. Angelova, "Gamification in education: A systematic mapping study," *Educ. Technol. Soc.*, vol. 18, no. 3, pp. 75–88, 2015.
[9] J. Hamari, J. Koivisto, and H. Sarsa, "Does gamification work? A literature review of empirical studies on gamification," in *Proc. 47th Hawaii Int. Conf. System Sci.*, 2014, pp. 3025–3034.
[10] K. Seaborn and D. I. Fels, "Gamification in theory and action: A survey," *Int. J. Human-Comput. Studies*, vol. 74, pp. 14–31, 2015.
[11] M. D. Hanus and J. Fox, "Assessing the effects of gamification in the classroom: A longitudinal study on intrinsic motivation, social comparison, satisfaction, effort, and academic performance," *Comput. Educ.*, vol. 80, pp. 152–161, 2015.
[12] M. R. Lepper, D. Greene, and R. E. Nisbett, "Undermining children's intrinsic interest with extrinsic reward: A test of the 'overjustification' hypothesis," *J. Pers. Soc. Psychol.*, vol. 28, no. 1, pp. 129–137, 1973.
[13] B. Ljung Aust, J. Eliasson, E. Allenmark, and S. De Verdier, "Safety culture in maritime operations," in *Maritime Safety Management and Risk-Based Decision Making*, P. M. Schröder-Hinrichs, Ed. Abingdon, U.K.: Routledge, 2020, pp. 211–229.
[14] L. de Sousa Borges, V. J. Reis, V. H. S. Durelli, R. S. Bittencourt, P. A. Jaques, and S. Isotani, "A systematic mapping on gamification applied to education," in *Proc. 29th ACM Symp. Appl. Comput.*, 2014, pp. 216–222.
[15] J. W. Creswell and V. L. Plano Clark, *Designing and Conducting Mixed Methods Research*, 3rd ed. Thousand Oaks, CA, USA: SAGE Publications, 2018.
[16] R. K. Yin, *Case Study Research and Applications: Design and Methods*, 6th ed. Thousand Oaks, CA, USA: SAGE Publications, 2018.
[17] V. Braun and V. Clarke, "Using thematic analysis in psychology," *Qual. Res. Psychol.*, vol. 3, no. 2, pp. 77–101, 2006.
[18] J. Cohen, *Statistical Power Analysis for the Behavioral Sciences*, 2nd ed. Hillsdale, NJ, USA: Lawrence Erlbaum Associates, 1988.
[19] F. I. M. Craik and R. S. Lockhart, "Levels of processing: A framework for memory research," *J. Verbal Learn. Verbal Behav.*, vol. 11, no. 6, pp. 671–684, 1972.
[20] J. D. Bransford, A. L. Brown, and R. R. Cocking, Eds., *How People Learn: Brain, Mind, Experience, and School*, Expanded ed. Washington, DC, USA: National Academy Press, 2000.