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IoT-Based Competency Tracking Systems for Seafarer Training Management: Automated Performance Monitoring and Skill Gap Identification in Indonesian Maritime Academies

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ABSTRACT

Internet of Things (IoT)-based competency tracking systems represent a transformative advancement in maritime training management, enabling automated, real-time monitoring of student skill development, objective performance assessment, and data-driven identification of competency gaps that manual assessment methods cannot match in precision, timeliness, or scalability. Yet the full realization of these technological capabilities is critically constrained by a utilization gap between what IoT tracking systems can provide and how instructors actually employ these systems in training practice. This mixed-methods study investigates IoT competency tracking system implementation at Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta through secondary analysis of system usage logs (N=17 instructors, 847 student records) and Focus Group Discussions with maritime academy students (n=22) and training instructors (n=17). Findings reveal that while IoT tracking systems generate comprehensive, granular competency data across navigation, engineering, and safety training domains, instructors utilize only 22.3 percent of advanced analytical features, relying primarily on basic attendance and pass/fail recording while underutilizing skill gap diagnosis, personalized intervention planning, and longitudinal competency development tracking capabilities. Competency data completeness rates of 70.5 percent and average entry delays of 4.1 days further compromise system effectiveness. Instructor training deficits (38%), time constraints (28%), and data interpretation confidence gaps (18%) emerge as primary utilization barriers. The study proposes an IoT Competency Tracking Utilization Framework integrating comprehensive faculty development, dedicated system interaction time, ongoing technical support, and institutional accountability mechanisms for closing the capability-utilization gap and ensuring maritime graduate competency outcomes align with STCW requirements.

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1. INTRODUCTION

The competency-based training paradigm that has dominated global maritime education since the International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW) 1978 amendments fundamentally transformed how maritime academies conceptualize, deliver, and assess professional preparation for seafaring careers [1]. Unlike traditional knowledge-based educational models that measure student achievement through theoretical examinations and course completion metrics, competency-based training requires maritime education institutions to demonstrate that graduates can actually perform the practical tasks, apply the technical knowledge, and exhibit the professional behaviors required for safe and effective shipboard operation—a standard that demands continuous assessment of student performance across diverse practical training contexts and rigorous documentation of competency development trajectories from novice through to certified professional levels [2]. This assessment and documentation burden has historically imposed substantial administrative overhead on maritime training institutions, requiring instructors to manually record performance observations, aggregate assessment data across multiple training stations and exercises, identify individual student competency gaps requiring remediation, and maintain comprehensive training records that satisfy both institutional quality assurance requirements and regulatory compliance obligations under STCW and national maritime authority frameworks [3].

The administrative complexity of competency-based maritime training is further compounded by the inherently multifaceted nature of seafaring competencies themselves. A certified deck officer must demonstrate proficiency across navigation and watchkeeping, cargo operations and stowage, ship stability and construction, meteorology and oceanography, collision avoidance and Rules of the Road, emergency response and crisis management, maritime communication protocols, and human resource management—each competency domain comprising multiple specific skills that must be assessed individually, documented comprehensively, and integrated into holistic professional capability [4]. Similarly, marine engineering officers require documented competency in thermodynamic cycles and heat transfer, auxiliary machinery operation and maintenance, electrical systems and automation, propulsion plant troubleshooting, workshop fabrication techniques, planned maintenance systems, and emergency repair procedures [5]. Maritime safety specialists must demonstrate life-saving appliance operation, firefighting equipment deployment, damage control procedures, medical first aid provision, search and rescue coordination, and hazardous material handling protocols. The International Maritime Organization's model courses specify detailed learning objectives, assessment criteria, and documentation requirements for each competency element, creating an assessment matrix that can include 150 to 250 individual competency items per training program that must be systematically assessed, recorded, and verified before certification [6].

Traditional paper-based competency tracking systems—the training record books and assessment checklists that have served maritime education for decades—struggle to manage this documentation complexity effectively. Instructors conducting bridge simulator sessions or engine room practical exercises must simultaneously supervise student performance, provide real-time coaching and corrective feedback, ensure safety protocol compliance, manage equipment operation, and document competency achievements for each individual student across multiple assessment criteria—a cognitive load that frequently results in incomplete recording, delayed documentation, and assessment data that are too coarse-grained to support precise skill gap identification [7]. The reliance on manual record-keeping creates systematic data quality problems: assessments recorded hours or days after training exercises suffer from instructor recall bias; paper records are vulnerable to loss, damage, and retrospective alteration; aggregating performance data across multiple training stations and instructors to generate comprehensive student competency profiles requires labor-intensive manual compilation; and extracting institutional-level insights about curriculum effectiveness or systematic competency development challenges from individual paper records is practically infeasible [8].

Internet of Things (IoT) technologies offer a transformative solution to this assessment and documentation challenge through automated competency tracking systems that leverage networked sensors, RFID identification, digital assessment interfaces, and cloud-based data aggregation platforms to continuously monitor, record, and analyze student performance across all training activities without requiring manual instructor record-keeping [9]. In a contemporary IoT-enabled maritime training environment, students wear RFID-tagged identification badges that automatically log their presence at specific training stations—bridge simulators, engine room mock-ups, lifeboat davit systems, fire-fighting facilities, cargo handling equipment, GMDSS communication suites—enabling precise tracking of which competency-building activities each student has completed, how much time they have invested in each skill domain, and whether they have met the minimum training hour requirements specified by STCW for each competency area [10]. Digital assessment tablets integrated with simulator systems and practical training equipment allow instructors to record performance ratings, competency achievement levels, and qualitative observations directly into the tracking system during or immediately following training exercises, eliminating paper-based recording delays and ensuring that assessment data are immediately available for aggregation and analysis [11].

Beyond simple digitization of manual recording processes, advanced IoT competency tracking platforms incorporate sophisticated analytical capabilities that generate pedagogical value impossible to achieve with paper-based systems. Machine learning algorithms analyze accumulated performance data to

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identify patterns indicative of specific skill gaps—a student who consistently struggles with radar plotting tasks but excels in visual navigation, or an engineering student who demonstrates strong thermodynamic knowledge but weak troubleshooting competency—enabling early intervention and personalized remediation before competency deficits become entrenched [12]. Predictive analytics can identify students at risk of failing certification assessments based on their competency development trajectories, allowing instructors to provide intensive support before critical evaluation points. Learning pathway optimization algorithms can recommend individualized practice sequences that prioritize the specific competency elements where each student needs the most development, making more efficient use of limited simulator access and instructor supervision time [13]. Longitudinal competency tracking features enable instructors and students to visualize skill development over time, identifying not just current competency status but the rate of improvement and the effectiveness of specific training interventions in accelerating competency acquisition [14].

The pedagogical and administrative value proposition of IoT competency tracking systems is compelling across multiple stakeholder dimensions. For students, real-time access to their competency development dashboards provides continuous feedback on skill mastery progression, transparent visibility into remaining competency requirements for certification, and self-directed learning guidance identifying specific practice areas requiring additional attention—transforming competency tracking from an administrative compliance function into an active learning support tool that empowers student agency in their own professional development [15]. For instructors, automated tracking eliminates the manual record-keeping burden that in traditional maritime training contexts can consume 15 to 25 percent of instructor time, liberating that cognitive capacity for direct student interaction, training design improvement, and professional development activities that have higher pedagogical value than data entry [16]. The reduction in documentation workload is particularly significant for maritime training contexts where a single instructor may supervise ten to fifteen students across complex practical exercises, making real-time manual recording of individual performance practically impossible without compromising supervision quality or training safety.

For training coordinators and academic administrators, aggregated competency data enable institutional-level quality assurance through identification of systematic curriculum gaps where student cohorts consistently underperform, evidence-based resource allocation directing instructor time and facility access toward the training domains where competency development is weakest, and regulatory compliance documentation demonstrating that training programs systematically develop the full range of STCW-mandated competencies rather than focusing disproportionately on certain skill areas while neglecting others [17]. The ability to generate cohort-level competency profiles—showing, for example, that navigation students across multiple training groups consistently struggle with electronic chart display and information systems (ECDIS) route planning but perform well on traditional chart navigation—enables targeted curriculum revision and instructor professional development that address systematic training weaknesses rather than treating each student competency deficit as an isolated individual problem. IoT tracking data can also support evidence-based decisions about training equipment investment and facility expansion by quantifying bottlenecks where student access to specific training resources (simulator stations, practical equipment, specialized facilities) limits competency development opportunities [18].

For external auditors—classification societies, flag state inspectors, and STCW compliance assessors—IoT tracking systems provide auditable digital records of competency development that are more reliable, comprehensive, and tamper-resistant than paper-based training record books that have historically been vulnerable to incomplete recording, retrospective fabrication, and loss [19]. The comprehensive audit trail that IoT systems generate—documenting not just competency achievement but the complete training process including attendance patterns, practice time distribution, assessment timing, instructor identity, and competency development trajectories—enables more rigorous verification that maritime academies are actually delivering the systematic, comprehensive competency development that STCW requires rather than simply documenting that students have completed required training hours without genuine skill acquisition. This enhanced auditability is particularly valuable in the context of recent IMO emphasis on maritime education quality standards and concerns about diploma mills that issue STCW certificates without providing adequate training [20].

Yet the realization of these theoretical benefits is not automatic upon IoT competency tracking system installation but depends critically on the extent to which instructors and administrators actually utilize the system's full functional capabilities in their training management practice. Educational technology research has consistently documented a "utilization gap" phenomenon across diverse technology-enhanced learning contexts: sophisticated systems are installed and made available to instructors, but actual usage patterns reveal that only a subset of system features—often the simplest, most familiar functions that most closely replicate pre-existing manual workflows—are regularly employed, while more advanced analytical and decision-support features remain underutilized or unused despite their potential pedagogical value [21]. This utilization gap is particularly pronounced for data-intensive systems like IoT competency trackers, where instructor capacity to interpret performance analytics, translate data insights into pedagogical action, and integrate technology-mediated assessment into established training routines determines whether installed systems generate transformative training improvements or merely digitize existing practices without fundamental pedagogical change [22].

Multiple theoretical frameworks help explain why educational technology utilization gaps emerge and persist even when systems offer clear pedagogical advantages. The Technology Acceptance Model posits that actual system usage is predicted by perceived usefulness and perceived ease of use, suggesting that utilization gaps arise when instructors do not recognize how tracking system features support their training objectives or find system interfaces too complex to navigate efficiently during time-pressured training contexts [23]. The Concerns-Based Adoption Model identifies six stages of technology adoption—awareness, information, personal, management, consequence, collaboration, and refocusing—and suggests that most instructors remain at early adoption stages focused on basic operational competency rather than advancing to later stages where they refine usage based on student outcome data and collaborate with colleagues to optimize system deployment [24]. Social cognitive theory emphasizes that technology adoption requires not just access to tools but development of self-efficacy beliefs about one's capacity to use those tools effectively, suggesting that utilization gaps persist when instructors lack confidence in their data interpretation skills or doubt their ability to design effective interventions based on analytical insights [25].

The Indonesian maritime education context presents particular challenges for IoT competency tracking system adoption that may exacerbate utilization gaps beyond those documented in developed maritime education systems. Many maritime academy instructors in Indonesia have extensive practical seafaring experience but limited formal pedagogical training and minimal exposure to educational technology or learning analytics, creating a professional development gap that constrains their capacity to leverage data-intensive training support systems [26]. Indonesian maritime academies often operate with higher student-to-instructor ratios than Western institutions, creating time pressure that may prevent instructors from engaging with analytical features that require sustained attention to interpret and act upon [27]. Infrastructure limitations—unreliable internet connectivity, limited technical support capacity, insufficient training in system operation—can undermine system functionality and erode instructor confidence that IoT platforms will operate reliably when needed [28]. Cultural factors emphasizing hierarchical authority relationships and instructor-centered pedagogy may create resistance to data-driven approaches that make student competency gaps visible to administrators and potentially subject instructors to performance accountability based on their students' competency development outcomes [29].

Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta's implementation of IoT-based competency tracking systems across its navigation bridge simulator complex, marine engineering workshop facilities, and maritime safety training center provides an important empirical context for investigating this utilization gap within Indonesian maritime education. The institution has invested substantially in IoT infrastructure—RFID student identification systems deployed across all training facilities, digital assessment tablets for all training instructors enabling real-time competency recording, cloud-based competency management platforms integrating data from multiple training domains, and learning analytics dashboards designed to support data-driven training decision-making through visualization of individual student competency profiles, cohort-level performance patterns, and longitudinal skill development trajectories [30]. Yet informal observations and preliminary instructor surveys suggest that system utilization may fall substantially short of installed capability, with many instructors continuing to rely on supplementary paper-based records, making limited use of analytical features, and expressing uncertainty about how to interpret or act upon the competency data the system generates.

This investigation is both timely and practically consequential for Indonesian maritime education development. Indonesia's status as the world's largest archipelagic nation and a major seafarer-supplying country makes the quality of maritime training a matter of national economic and safety significance, with over 1.2 million Indonesian seafarers working on domestic and international vessels and maritime training quality directly affecting both seafarer employability in competitive global labor markets and the safety performance of Indonesian-flagged and Indonesian-crewed vessels [31]. Recent growth in Indonesian maritime academy enrollments—driven by government initiatives to develop the domestic maritime sector and increase youth participation in maritime careers—has created training capacity challenges that make the efficient, data-driven training management that IoT systems enable particularly valuable [32]. Understanding the barriers preventing full IoT system utilization and developing evidence-based strategies for closing the capability-utilization gap can inform not just STIP Jakarta's technology optimization efforts but also guide IoT implementation planning at other Indonesian maritime academies considering similar investments.

This study is guided by the central research question: What is the magnitude of the gap between IoT competency tracking system capability and actual instructor utilization at STIP Jakarta, and what instructor competency deficits, institutional support gaps, and system design limitations most critically constrain full system utilization? The investigation addresses three specific objectives: (1) quantify the utilization rates for basic recording features versus advanced analytical features across different instructor groups and training domains; (2) assess competency data completeness and timeliness as indicators of whether even basic system functions are being employed comprehensively; and (3) identify from instructor and student perspectives the specific barriers, training needs, and institutional support requirements that must be addressed to close the utilization gap and realize the pedagogical potential of IoT competency tracking investment.

2. RESEARCH METHOD

This study employed a convergent mixed-methods research design integrating secondary analysis of IoT competency tracking system usage logs with qualitative Focus Group Discussions (FGDs) to investigate the gap between system capability and instructor utilization at STIP Jakarta [33]. The convergent design was selected because quantitative usage data alone can document what utilization patterns exist but cannot explain why those patterns occur, while qualitative data alone would be vulnerable to self-report bias where instructors might overestimate their system usage or misattribute the causes of underutilization. By integrating objective system-generated usage metrics with rich qualitative explanations from the instructors who underutilize systems and the students who experience the consequences of underutilization, the convergent approach enables both precise quantification of the utilization gap and deep understanding of the mechanisms generating that gap [34].

The secondary data analysis stream provided objective, system-generated quantification of which tracking system features are utilized, with what frequency, by which instructor groups, and for which training domains—data that are immune to the self-report bias and social desirability effects that would affect survey-based utilization measurement [35]. The FGD stream generated rich qualitative understanding of why utilization gaps exist from the perspectives of multiple stakeholder groups, enabling identification of the specific barriers, competency deficits, and institutional support gaps that must be addressed to close the utilization gap. Integration occurred at the interpretation stage through joint display analysis positioning quantitative utilization metrics within the qualitative explanatory framework that the FGD data provide, enabling meta-inferences that neither data stream alone could support [36].

Secondary usage data were obtained from STIP Jakarta's IoT competency tracking system administrative database, covering the full 2023 academic year (January–December 2023) during which the system was operational across all training programs. The database contains comprehensive logs of all instructor interactions with the system, automatically recording login events, feature access, assessment entries, data exports, and analytical tool usage with timestamps enabling precise temporal analysis. Usage metrics extracted included: instructor login frequency and session duration measuring basic system access patterns; utilization rates for basic features (attendance recording, pass/fail assessment entry) versus intermediate features (detailed performance scoring, qualitative observation notes) versus advanced features (skill gap analytics viewing, personalized intervention planning, longitudinal competency progression visualization, competency dashboard sharing with students); competency data completeness rates measuring the proportion of required assessment entries actually recorded relative to the number of training activities conducted; and time-to-entry metrics capturing the delay between training activity completion and assessment data entry into the system.

Data were disaggregated by instructor training domain (navigation, marine engineering, maritime safety), instructor experience level (junior: <5 years teaching; senior: ≥5 years teaching), and student program (diploma, bachelor's degree) to enable identification of utilization pattern variations across institutional subgroups. Utilization rates were calculated as (Actual Feature Usage Events / Potential Usage Opportunities) × 100, where potential usage opportunities were defined based on the number of training sessions conducted that could have employed each feature. Descriptive statistics, utilization rate calculations, cross-tabulation analyses, and comparative statistics were performed using SPSS version 26.

For the qualitative FGD phase, four focus group sessions were conducted in November 2023: two with training instructors and assessors (n=8-9 each, total n=17) and two with maritime academy students and cadets (n=10-12 each, total n=22). Purposive sampling was employed to ensure representation across training domains, experience levels, and program types [37]. Instructor FGDs explored current system utilization practices, perceived benefits and limitations of different features, barriers to advanced feature adoption, training needs for data analytics interpretation, confidence levels in using various system components, time allocation for system interaction during training schedules, and recommendations for system improvement and institutional support enhancement. Student FGDs examined their experiences accessing competency tracking data, perceived benefits and limitations of automated versus manual assessment, visibility of their own competency development patterns, experiences with instructor use of tracking data for personalized learning support, and suggestions for how instructors could better leverage tracking systems to support their learning needs.

FGD sessions lasted 95 to 115 minutes, were conducted in Indonesian language by trained facilitators using semi-structured discussion guides, and were audio-recorded with informed consent. Recordings were transcribed verbatim and translated into English for analysis. Thematic analysis following Braun and Clarke's six-phase framework was employed: familiarization with data through repeated reading of transcripts, systematic coding of meaningful text segments, collation of codes into potential themes, review and refinement of themes against coded data and full transcripts, definition and naming of final themes, and selection of illustrative quotations [38]. Cross-session comparison identified both instructor-specific and student-specific themes as well as convergent cross-stakeholder perspectives on utilization barriers. Ethical approval was obtained from STIP Jakarta's research ethics committee, and all participants provided written informed consent prior to data collection.

3. RESULTS

The integrated analysis of system usage logs and FGD data produced compelling evidence of a substantial and pedagogically consequential utilization gap: while the IoT competency tracking system installed at STIP Jakarta offers comprehensive functionality across basic recording, intermediate assessment, and advanced analytical domains, instructors utilize only 22.3 percent of advanced features and record only 70.5 percent of required competency assessments, concentrating usage on attendance logging and basic pass/fail recording while severely underutilizing the analytical capabilities that represent the system's primary pedagogical value proposition.

Table 1. IoT Competency Tracking System Feature Utilization Rates by Domain (Academic Year 2023, N=17 instructors)

System Feature Category	Navigation Instructors (n=6)	Engineering Instructors (n=6)	Safety Instructors (n=5)	Overall Utilization Rate	Capability Category
Basic Attendance Recording	94.3%	91.7%	96.2%	94.1%	Basic
Pass/Fail Assessment Entry	87.4%	83.9%	89.1%	86.8%	Basic
Detailed Performance Scoring	61.2%	58.7%	64.3%	61.4%	Intermediate
Qualitative Observation Notes	42.8%	38.4%	47.6%	42.9%	Intermediate
Skill Gap Analytics Viewing	31.7%	28.3%	34.8%	31.6%	Advanced
Personalized Intervention Planning	24.1%	21.6%	27.4%	24.4%	Advanced
Longitudinal Progress Tracking	18.9%	16.2%	21.7%	18.9%	Advanced
Competency Dashboard Sharing	14.3%	11.8%	16.9%	14.3%	Advanced
Overall Advanced Feature Utilization	22.3%	19.5%	25.2%	22.3%	Advanced

Note: Utilization Rate = (Actual Feature Usage Events / Potential Usage Opportunities) × 100. Data: STIP Jakarta IoT System Logs, January–December 2023

The utilization pattern reveals a stark capability-usage divergence. Basic recording features (attendance, pass/fail) are utilized at rates above 85 percent, indicating near-universal instructor adoption of these fundamental functions that most closely replicate pre-existing manual workflows. Intermediate features (detailed scoring, qualitative notes) show moderate utilization at 42.9 to 61.4 percent, suggesting partial adoption of capabilities requiring greater data entry effort. Advanced analytical features demonstrate severe underutilization at rates below 32 percent, with longitudinal progress tracking (18.9%) and competency dashboard sharing (14.3%) particularly neglected despite their high pedagogical value for student self-directed learning. The overall advanced feature utilization rate of 22.3 percent means that approximately three-quarters of the pedagogical value that the system's analytical capabilities could provide remains unrealized due to instructor underutilization.

Table 2. Competency Assessment Data Completeness Rates by Training Domain (N=847 student training records)

Training Domain	Required Assessment Entries	Actual Entries Recorded	Completeness Rate	Average Entry Delay (days)	Data Quality Rating
Navigation Bridge Simulation	3,388	2,447	72.2%	3.8	Moderate
Marine Engineering Practical	2,964	2,038	68.8%	4.6	Moderate
Maritime Safety & Firefighting	2,116	1,627	76.9%	2.9	Moderate-Good
Cargo Handling Operations	1,692	1,098	64.9%	5.2	Low-Moderate
GMDSS Communication	1,328	891	67.1%	4.1	Moderate
Overall Fleet Average	11,488	8,101	70.5%	4.1	Moderate

Data: STIP Jakarta IoT Competency Tracking System, Academic Year 2023

The overall competency data completeness rate of 70.5 percent indicates that nearly one-third (29.5%) of required competency assessments are not being recorded in the tracking system, creating systematic gaps in student training records that undermine both the pedagogical value of continuous competency monitoring and the regulatory compliance function of comprehensive documentation. The variation across training domains—from 76.9 percent completeness in maritime safety to 64.9 percent in cargo handling—suggests that utilization challenges are more severe in certain training contexts. The average entry delay of 4.1 days between training activity completion and assessment recording further compromises data utility, as delayed entry prevents the real-time feedback and immediate intervention that IoT tracking systems are designed to enable.

Table 3. Instructor-Reported Barriers to IoT System Utilization (FGD Data, n=17 instructors)

Barrier Category	Frequency of Mention	Percentage of Instructors	Representative Quotations
Training Deficit on Advanced Features	13	38%	"We only got basic orientation on attendance and pass/fail entry, never learned how to use the analytics tools"
Time Pressure During Training	10	28%	"When I'm supervising 12 students on bridge simulator, I don't have time to interact with complex analytics interfaces"
Data Interpretation Confidence Gap	6	18%	"I see the skill gap charts but I'm not sure what intervention would actually fix the problem the data shows"
System Interface Complexity	4	12%	"The advanced features have too many options and settings, it's overwhelming when you're trying to work quickly"
Insufficient Technical Support	3	9%	"When I have questions about using features, there's no one available to help figure it out"

Note: Instructors could mention multiple barriers; percentages total >100%

The FGD data generated rich qualitative understanding of the mechanisms generating the utilization gap documented in the quantitative system logs. The dominant cross-session theme among instructors was the "training deficit barrier" (38 percent of instructors)—participants consistently reported that they received only basic orientation on attendance recording and assessment entry functions during initial system deployment but never received comprehensive training on how to interpret skill gap analytics, design personalized interventions based on competency data, or use longitudinal tracking features to monitor student development over time. This training deficit creates a competency gap: instructors possess the technical knowledge to operate basic recording functions but lack the data literacy and analytical competency required to leverage advanced features effectively.

A second prominent theme was "time pressure during training delivery" (28 percent of instructors)—participants described how the immediate demands of supervising live training exercises, providing real-time feedback to students, maintaining safety during practical activities, managing equipment operation, and responding to student questions leave minimal attention available for interacting with tracking system interfaces, particularly the more complex analytical features that require sustained cognitive engagement to interpret effectively. One engineering instructor explained: "During a four-hour engine room practical session with twelve students working on different systems, I'm constantly moving between stations, checking procedures, preventing errors, answering questions. The idea that I would stop and spend ten minutes analyzing competency dashboards is completely unrealistic."

Students in the FGDs articulated a complementary perspective focused on the consequences of instructor underutilization. The dominant student theme was "invisible competency gaps"—participants described situations where they struggled with specific skills (radar collision avoidance, engine troubleshooting procedures, lifeboat davit operation) but instructors failed to identify these struggles systematically because they were not using the skill gap analytics features that would have made the patterns visible across multiple training sessions. Students consistently expressed frustration that competency tracking data exist in the system but are not being used to provide them with the personalized learning support and targeted remediation that the data could enable if instructors utilized advanced features more comprehensively. One navigation student stated: "I know the system tracks every simulator session, but my instructor never shows me my competency profile or explains which specific skills I need to focus on. I'm preparing for certification exams without really knowing where my weak areas are."

4. DISCUSSION

The findings of this study provide the first systematic empirical documentation of the utilization gap between IoT competency tracking system capability and actual instructor practice at STIP Jakarta, revealing that advanced analytical features are utilized at only 22.3 percent of potential opportunities and that nearly one-third of required competency assessments are not recorded in the system at all. This utilization gap has direct and consequential implications for training quality: when instructors record attendance and pass/fail outcomes but do not utilize skill gap analytics to identify struggling students early, do not employ intervention planning features to design targeted remediation, and do not share competency dashboards to enable student self-directed learning, the sophisticated IoT infrastructure investment generates only modest improvements over paper-based record-keeping rather than the transformative training optimization that the system's full capabilities could enable [39].

These findings align with broader educational technology literature documenting systematic underutilization of advanced learning analytics features across diverse educational contexts. Viberg et al.'s systematic review of learning analytics in higher education found that while 73 percent of institutions have implemented learning analytics platforms, only 31 percent report widespread faculty use of predictive or prescriptive analytics, with most usage concentrated on basic reporting functions [40]. Similarly, Siemens and Long documented that learning management systems with sophisticated analytics capabilities are typically used primarily for content distribution and grade recording rather than for the diagnostic and intervention support functions that represent their pedagogical innovation [41]. The STIP Jakarta findings extend this pattern specifically to maritime education contexts and to IoT-based tracking systems, suggesting that the utilization gap phenomenon is robust across educational sectors and technology types.

The FGD-identified "training deficit barrier" as the primary utilization obstacle (38 percent of participants) carries particularly important implications for institutional technology adoption strategy at STIP Jakarta and other maritime academies implementing IoT competency tracking systems. The finding suggests that the dominant approach to educational technology deployment—purchasing and installing sophisticated systems with minimal faculty development investment—is fundamentally inadequate for technologies like IoT tracking platforms whose value proposition depends critically on instructor capacity to interpret complex analytics and translate data insights into pedagogical action [42]. West, Huijser, and Heath similarly documented that learning analytics adoption in higher education fails when institutions assume that data availability automatically generates data use, without recognizing that effective data-driven teaching requires explicit competency development in statistical reasoning, dashboard interpretation, intervention design, and the integration of analytics into established pedagogical routines [43].

This finding establishes faculty development not as an optional supplement to IoT tracking system deployment but as an essential prerequisite without which advanced feature utilization will remain systematically low regardless of system sophistication. Effective faculty development for IoT competency tracking must go beyond basic operational training to develop instructor capabilities in: (1) statistical reasoning and data interpretation sufficient to understand what performance patterns in analytics dashboards signify about student learning challenges; (2) pedagogical intervention design translating diagnostic insights into specific teaching actions—additional practice exercises, revised instructional explanations, peer tutoring arrangements, prerequisite skill remediation—that address identified competency gaps; (3) formative assessment philosophy recognizing competency tracking as a learning support function rather than purely a documentation requirement; and (4) workflow integration strategies for incorporating data review and intervention planning into time-constrained training schedules [44].

The competency data completeness rate of 70.5 percent—indicating that nearly one-third of required assessments are never recorded—reveals a more fundamental challenge beyond the advanced feature utilization gap: even basic recording functions are not being used comprehensively, suggesting that the utilization problem extends across the full spectrum of system capabilities rather than being limited to advanced analytics alone. The average entry delay of 4.1 days between activity completion and data recording further undermines system value by preventing the real-time feedback and immediate intervention that represent IoT tracking's primary advantage over periodic manual assessment [45].

These data quality deficits point to the need for institutional accountability mechanisms—regular audits of data completeness, supervisor review of entry timeliness, performance management systems that recognize comprehensive recording as a professional responsibility, and integration of tracking system usage into instructor evaluation criteria—to ensure that instructors fulfill the documentation responsibilities that IoT systems are designed to support rather than replace [46]. Without such accountability mechanisms, voluntary adoption of even basic recording functions appears insufficient to achieve the comprehensive data capture that competency-based training requires. The variation in completeness rates across training domains (64.9% to 76.9%) suggests that domain-specific challenges—perhaps related to the physical layout of training facilities, the complexity of assessment criteria, or the instructor-student ratios during practical exercises—require tailored implementation strategies rather than uniform institutional policies.

The time pressure barrier identified by 28 percent of instructors warrants careful consideration in system interface design and training schedule planning. The finding suggests that advanced analytical features, while pedagogically valuable, may have been designed with implicit assumptions about instructor workflow that do not match the realities of maritime practical training contexts where continuous student supervision is essential for safety and learning. This points to a need for: (1) simplified analytical interfaces optimized for rapid interpretation during brief intervals between training activities rather than requiring extended focused analysis; (2) mobile-optimized dashboards enabling instructors to review competency data while physically present in training facilities rather than requiring return to office computers; (3) automated alerts and notifications that proactively push critical competency gap information to instructors rather than requiring them to pull data through complex navigation; and (4) scheduled dedicated time within instructor workload allocations specifically for data review and intervention planning, recognizing this as legitimate professional work rather than an additional burden to be accommodated within existing schedules [47].

The data interpretation confidence gap (18% of instructors) reflects a deeper challenge about the relationship between seafaring expertise and educational data analytics. Many maritime instructors bring extensive practical shipboard experience and technical knowledge of navigation, engineering, or safety operations but have limited background in educational assessment, statistical reasoning, or evidence-based pedagogical decision-making [48]. The assumption that instructors will naturally know how to translate skill gap analytics into effective teaching interventions underestimates the specialized knowledge required for diagnostic teaching. Professional development must bridge this gap through concrete, domain-specific examples showing how particular performance patterns in navigation, engineering, or safety training data should inform specific pedagogical responses, rather than assuming that instructors can independently develop this interpretive competency [49].

The integration of quantitative utilization metrics with qualitative explanatory themes enables the development of an evidence-based IoT Competency Tracking Utilization Framework for STIP Jakarta comprising four interconnected intervention strategies: (1) Comprehensive Faculty Development Programs—multi-stage training progressing from basic operation through data interpretation to intervention design, with ongoing mentoring and peer learning communities; (2) Workflow Integration Support—dedicated time allocation for data review within instructor schedules, mobile-optimized interfaces enabling facility-based system access, and simplified analytical displays requiring minimal interpretation effort; (3) Institutional Accountability Mechanisms—regular completeness audits, supervisor review of recording timeliness, performance expectations for system utilization, and recognition of data-driven teaching as professional competency; and (4) Continuous System Optimization—iterative interface refinement based on instructor feedback, technical support capacity enhancement, and alignment of analytical features with actual instructor decision-making needs rather than theoretical capabilities [50].

5. CONCLUSION

This mixed-methods study has revealed a critical and pedagogically consequential utilization gap in IoT competency tracking implementation at STIP Jakarta: while the installed system offers comprehensive functionality across basic recording, intermediate assessment, and advanced analytical domains, instructors utilize only 22.3 percent of advanced features and record only 70.5 percent of required competency assessments, leaving the majority of the system's pedagogical potential unrealized. Insufficient training on advanced features (38 percent of participants), time constraints during training delivery (28 percent), and lack of confidence in data interpretation (18 percent) emerge as the primary barriers preventing full system utilization. The IoT Competency Tracking Utilization Framework proposed by this study—integrating comprehensive faculty development on data analytics and intervention design, dedicated time allocation for system interaction within instructor schedules, ongoing technical support and mentoring structures, and institutional accountability mechanisms for data completeness and utilization quality—provides STIP Jakarta with an evidence-grounded strategy for closing the capability-utilization gap and ensuring that IoT infrastructure investment translates into realized training quality improvements that enhance maritime graduate competency outcomes and STCW compliance quality. Future research should investigate the effectiveness of specific faculty development interventions in increasing advanced feature utilization and examine whether enhanced instructor system usage correlates with improved student competency development outcomes and certification examination performance.

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