

E-Portfolio Systems for Seafarer Competency Documentation: Blockchain-Enabled Digital Credentialing and Career Development Tracking

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ABSTRACT

Electronic portfolio (e-portfolio) systems—comprehensive digital platforms enabling seafarers to systematically collect, organize, securely store, and selectively share professional competency documentation including STCW certificates of competency, specialized training completion records, sea service discharge books, medical fitness certificates, performance evaluations, and continuing professional development achievements—offer transformative potential for addressing the inefficiencies, authentication vulnerabilities, and administrative burdens inherent in traditional paper-based seafarer credential management systems that have dominated maritime employment verification processes since the establishment of international certification standards. When strategically integrated with blockchain technology employing distributed ledger architectures, cryptographic digital signature validation mechanisms, and immutable transaction recording protocols, e-portfolios provide tamper-proof, instantly verifiable credential records directly addressing the authentication challenges, fraud vulnerabilities, and verification delays that have plagued maritime credentialing for decades. This mixed-methods comparative study investigates blockchain-enabled e-portfolio system implementation at Sekolah Tinggi Ilmu Pelayaran (STIP) Jakarta through systematic pilot deployment with graduating officer cadets (n=124) and controlled comparative assessment against traditional paper documentation cohorts (n=137), measuring employer credential verification efficiency, stakeholder confidence levels, and graduate career placement outcomes. Quantitative findings demonstrate that blockchain-enabled e-portfolios reduce employer credential verification time by 97.3 percent (from 14.7 to 0.4 days), decrease verification costs by 93.5 percent, improve graduate employment placement rates by 11.3 percentage points, and increase employer confidence in credential authenticity by 45.4 percent relative to traditional paper documentation systems. The study proposes an evidence-based E-Portfolio Implementation Roadmap for maritime education institutions incorporating phased industry partnership development, employer capacity building programs, regulatory engagement strategies, and hybrid paper-digital transition approaches.

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1. INTRODUCTION

The professional career trajectory of a modern seafarer generates substantial, continuous, and increasingly complex documentation requirements spanning multiple decades, diverse certification authorities, and international jurisdictional boundaries. From initial entry into maritime education through retirement after potentially 30-40 years of seagoing service, seafarers accumulate extensive credential portfolios including: certificates of competency issued by flag state maritime authorities attesting to demonstrated proficiency in navigation, engineering, or other specialized operational disciplines; training completion certificates from maritime academies and IMO-approved training centers documenting successful completion of mandatory STCW courses including basic safety, advanced firefighting, medical first aid, and crisis management; medical fitness certificates issued by approved maritime physicians certifying seafarers meet stringent health standards for seagoing service; sea service discharge books maintained throughout careers recording detailed employment history including vessel names, types, routes, ranks held, and duties performed aboard each ship; mandatory safety training certifications for survival craft operations, radar navigation, electronic chart display systems, and ship security awareness; specialized endorsements for particular vessel types including tanker operations, liquefied gas carriers, passenger ships, or polar operations; and performance evaluations from ship masters and chief engineers documenting competency demonstration, professional development, and promotion readiness [1].

This extensive documentation serves multiple critical, legally mandated, and professionally consequential functions throughout seafarers' careers and employment cycles. Certificates must be presented to prospective employers during hiring processes to prove qualifications and legal authorization for specific shipboard positions, submitted to ship operators and manning agencies for crew qualification verification and regulatory compliance documentation, inspected by port state control (PSC) authorities during vessel inspections to verify that crew members hold appropriate certificates for their duties and that vessels comply with STCW manning requirements, presented to flag state maritime authorities when applying for certificate renewals or advanced endorsements to establish eligibility based on accumulated sea service and continuing education, and maintained as permanent professional records documenting career progression, specialized competencies acquired, vessels served aboard, and professional development achievements spanning entire maritime careers potentially extending four decades [2].

Yet traditional paper-based documentation systems—the predominant credential management approach that has characterized maritime employment processes since the establishment of international seafarer certification standards through the 1978 STCW Convention and its subsequent amendments—create multiple systemic inefficiencies, operational vulnerabilities, administrative costs, and security risks throughout credential issuance, verification, maintenance, and presentation processes [7]. Physical paper certificates face perpetual risks of loss, damage, or destruction through fire, water damage, theft during international travel, or simple misplacement during the frequent residential relocations characteristic of seafarer careers involving extended periods away from home, requiring costly and time-consuming reissuance procedures that may involve seafarers traveling to flag state capital cities, paying substantial administrative fees to maritime authorities, waiting weeks or months for replacement certificate production and authentication, and potentially losing employment opportunities during reissuance periods when they cannot provide valid certification documentation to prospective employers conducting hiring processes on compressed timelines [1].

Credential verification processes under paper-based systems require labor-intensive, delay-prone manual procedures: shipping company human resource personnel or manning agency recruitment staff must contact issuing maritime authorities—often located in foreign countries requiring international communication across time zones and language barriers—to confirm certificate validity and authenticity, attempt to check certificates against incomplete, non-standardized, and frequently offline digital databases maintained inconsistently by some but not all flag state administrations, or rely exclusively on visual inspection of security features including watermarks, holograms, special papers, and embossed seals that may be unfamiliar to verifiers from other jurisdictions and increasingly sophisticated to counterfeit using commercially available printing technology [3]. These verification procedures introduce substantial delays ranging from hours to weeks depending on issuing authority responsiveness, create verification failures when maritime authorities are unreachable due to limited office hours, staff shortages, or communication infrastructure limitations, and generate considerable administrative workload for maritime authorities processing thousands of verification requests annually that consume staff time and resources that could otherwise support higher-value safety oversight and regulatory enforcement activities [8].

Most critically from a maritime safety perspective, physical paper certificates remain vulnerable to multiple forms of fraud, counterfeiting, and falsification that have generated recurring maritime casualties and regulatory enforcement challenges documented by the International Maritime Organization (IMO) and regional port state control regimes. Fraudulent credentialing mechanisms include: sophisticated document forgery and E-Portfolio Systems for Seafarer Competency Documentation: Blockchain-Enabled Digital Credentialing and Career Development Tracking (*Derma Watty Sihombing*)

counterfeiting using high-resolution color printers, specialized paper stocks, and replicated security features producing fake certificates virtually indistinguishable from authentic documents without expert forensic examination or verification with issuing authorities; unauthorized document alteration modifying certificate details including competency levels, endorsement restrictions, or validity dates; bribery of corrupt officials within certification authorities to issue genuine but unearned certificates to applicants who have not completed required training or passed competency examinations; and operation of fraudulent "diploma mill" maritime training institutions that issue certificates without providing actual training or assessing competency, sometimes operating with official-appearing accreditation documentation that superficially suggests regulatory approval [6]. A comprehensive 2019 IMO analysis examining port state control detention data from multiple regional memoranda of understanding found that certificate fraud, invalid certification, and STCW compliance deficiencies represented approximately 8-12 percent of crew-related deficiencies identified during vessel inspections, indicating substantial ongoing prevalence of fraudulent credentialing despite existing regulatory frameworks, verification procedures, and enforcement mechanisms [7].

The aggregate economic costs of paper-based credentialing systems, when calculated across all stakeholder categories and global maritime operations, prove substantial and represent inefficiencies that digital alternatives could potentially eliminate or dramatically reduce. Maritime academies and approved training centers incur ongoing expenses for specialized security paper procurement, professional-grade printing and embossing equipment, physical storage infrastructure for certificate records and templates, dedicated personnel time processing certificate issuance requests and reissuance procedures, and international shipping costs for mailing certificates to graduates employed globally on vessels or residing in remote locations [9]. Individual seafarers bear direct costs including certificate storage and protection during frequent international relocations, replacement fees and travel expenses when certificates are lost or damaged, notarized translation expenses when seeking employment across language boundaries, and opportunity costs from employment delays during verification procedures or certificate reissuance periods when they cannot provide immediate documentation to employers conducting time-sensitive hiring processes [1].

Shipping companies and manning agencies employ dedicated human resource personnel for credential verification coordination, maintain proprietary databases tracking crew certification status and renewal requirements for fleet manning compliance, process verification requests with multiple flag state maritime authorities representing multinational crew compositions, and face operational disruptions including delayed crew changes when certificate issues prevent timely personnel replacements, and potential port state control detentions with associated costs, schedule delays, and reputational damage when crew certification deficiencies are discovered during vessel inspections [3]. Flag state maritime authorities allocate substantial administrative capacity to certificate production including security printing, embossing, and quality control; verification request processing requiring staff to research records, confirm authenticity, and respond to employers and other authorities; fraud investigation when counterfeit or altered certificates are discovered; and international information exchange for mutual recognition arrangements enabling seafarers certificated by one flag state to serve on vessels registered under different flags [7].

Electronic portfolio systems—broadly defined as comprehensive digital platforms enabling individuals to systematically collect, organize, securely store, selectively control access to, and strategically present credential documentation, work samples, competency demonstrations, and professional development records in structured digital formats accessible to authorized stakeholders including potential employers, regulatory authorities, educational institutions, and professional associations—offer technologically sophisticated solutions directly addressing each dimension of inefficiency, vulnerability, and cost inherent in traditional paper-based documentation systems [2]. Modern e-portfolio platforms provide cloud-based storage infrastructure eliminating physical loss risks while ensuring credential accessibility from any internet-connected device globally, enabling seafarers to access their complete credential portfolio whether aboard vessels, during shore leave, or while traveling between assignments without carrying physical certificate books vulnerable to loss or damage.

E-portfolio systems provide structured organizational frameworks enabling rapid credential retrieval through searchable databases, automated categorization by credential type or competency domain, chronological sorting, and customizable filtering, dramatically reducing the time required to locate specific certificates or compile credential packages for particular employment applications compared to manual searching through accumulated paper documentation spanning decades of career history [10]. Selective sharing controls enable fine-grained permission management allowing seafarers to provide prospective employers access to only credentials relevant for specific positions being applied for rather than exposing their entire professional history, set time-limited viewing permissions that automatically expire after hiring processes conclude, track which organizations have accessed which credentials and when, and revoke access immediately if employment negotiations terminate or security concerns arise [11].

Integration capabilities connecting e-portfolio platforms with institutional learning management systems, training center databases, and maritime authority certification systems enable automated credential capture and portfolio population without requiring manual documentation upload, ensuring comprehensive record completeness while eliminating the administrative burden of tracking training completions across multiple institutions throughout multi-decade careers [12]. These automated data flows also reduce documentation errors from manual transcription, ensure credential authenticity by eliminating opportunities for document alteration between issuance and portfolio inclusion, and maintain tamper-evident audit trails documenting credential issuance dates, issuing authorities, and any subsequent modifications [13].

When e-portfolio systems strategically incorporate blockchain technology—distributed ledger architectures that cryptographically secure transaction records across decentralized networks of nodes employing consensus mechanisms to validate new transactions without requiring centralized authority or trusted intermediaries—the fundamental authentication challenges that have plagued maritime certification systems for decades can be substantially mitigated through technological rather than institutional trust mechanisms [8]. In blockchain-enabled credentialing systems, when STIP Jakarta awards a Certificate of Competency to a graduating navigation officer who has successfully completed required coursework, passed comprehensive competency examinations, and accumulated mandatory training ship sea service, the institution creates a digital credential containing the graduate's verified identity information, certificate type and level, specific competency domains demonstrated, issuance date, validity period, any restrictions or endorsements, and STIP Jakarta's cryptographic digital signature, then records this credential as a transaction on a maritime education blockchain network accessible to authorized verifiers [8].

Employers receiving blockchain-verified digital credentials from job applicants can cryptographically confirm authenticity in seconds through one-click verification procedures: the employer's verification system receives the credential presentation, extracts the cryptographic signature, queries the blockchain network to retrieve the original credential issuance transaction record, compares the presented credential against the blockchain record using mathematical hash verification, and receives instant confirmation of whether the credential is authentic, unaltered, currently valid, and issued by the claimed institution—all without requiring any communication with STIP Jakarta, without accessing any centralized database that could experience outages or security compromises, and without relying on visual security feature inspection that requires specialized expertise and remains vulnerable to sophisticated counterfeiting [2]. This verification process contrasts dramatically with traditional manual verification requiring weeks of correspondence with foreign maritime authorities, database queries to systems with limited coverage and uncertain reliability, or exclusive reliance on document security features that determined fraudsters can replicate.

Despite these compelling theoretical advantages documented extensively in blockchain credentialing literature across educational sectors and the growing number of pilot implementations in university degree credentialing, professional certification, and vocational training contexts internationally, systematic empirical research examining e-portfolio implementation effectiveness, employer adoption patterns and barriers, and career outcome impacts in maritime education contexts remains remarkably limited [9]. Most existing e-portfolio research focuses on higher education degree programs, K-12 student assessment, or teacher professional development rather than technical-vocational education with its distinctive competency structures, industry employment patterns, and international mobility requirements. Maritime education contexts introduce unique considerations including international regulatory frameworks through STCW, multinational employment markets where graduates commonly work under flag states different from their nationality, port state control inspection requirements demanding immediate physical credential presentation, and conservative industry cultures with limited digital technology adoption compared to other professional sectors [3].

STIP Jakarta's comprehensive pilot e-portfolio program—providing all 2023 graduating cadets (n=124) in both navigation and marine engineering programs with fully-functional digital portfolios containing complete STCW certificates of competency, specialized training completion records, sea service discharge book documentation, academic transcripts, shipboard performance evaluations, and continuing professional development certifications, all accessible through secure mobile applications enabling credential sharing from smartphones and web portals providing desktop access—offers particularly valuable empirical context for investigating whether e-portfolio theoretical benefits translate into realized improvements in credential verification efficiency, employer confidence in credential authenticity, and graduate employment outcomes within both Indonesian domestic maritime labor markets and international shipping employment contexts where Indonesian seafarers compete globally [10].

This implementation represents not merely a technological experiment but a carefully designed research opportunity enabling systematic comparative assessment of outcomes for e-portfolio-equipped graduates versus traditional paper documentation cohorts from the immediately preceding graduation year, providing controlled comparison while holding constant factors including labor market conditions, regulatory

requirements, employer populations, and graduate competency levels as verified through identical academic standards and certification examinations. The e-portfolio system deployed integrates with STIP Jakarta's institutional student information systems ensuring comprehensive credential capture, incorporates blockchain verification through Ethereum-based smart contracts providing cryptographic authentication, and provides both seafarer-facing mobile applications for portfolio management and employer-facing verification interfaces for credential confirmation, creating end-to-end digital credentialing infrastructure comparable to systems being explored by leading maritime education institutions internationally [11].

The specific Indonesian maritime employment context provides additional research value given the country's position as one of the world's largest seafarer source nations with an estimated 200,000+ Indonesian seafarers serving aboard international vessels, creating substantial economic importance for seafarer employment facilitation, significant government policy interest in maritime workforce development, and practical urgency for innovations potentially improving Indonesian seafarer competitiveness in increasingly competitive global maritime labor markets where Filipino, Ukrainian, Chinese, and other national seafarer populations compete for limited officer positions aboard international fleets [1]. Any e-portfolio implementation lessons, adoption barriers identified, or outcome improvements documented at STIP Jakarta carry implications extending beyond the single institution to Indonesian maritime education policy more broadly and potentially to other developing country maritime education systems facing similar implementation challenges regarding digital infrastructure, employer readiness, and regulatory framework adaptation [12].

This study addresses the central research question: *To what extent do blockchain-enabled e-portfolio systems improve credential verification efficiency, employer confidence in credential authenticity, and seafarer career placement outcomes in Indonesian and international maritime labor markets, and what implementation strategies, industry coordination mechanisms, and regulatory engagement approaches enable successful e-portfolio adoption despite organizational, technical, and institutional barriers?*

Secondary research questions examine: (1) What specific verification efficiency improvements do blockchain-enabled e-portfolios generate compared to traditional paper documentation, measured through verification time, cost, and reliability metrics? (2) How does e-portfolio credential presentation impact employer confidence in credential authenticity and hiring decision-making processes? (3) What employment outcome advantages, if any, do e-portfolio-equipped graduates achieve compared to traditional paper documentation cohorts in terms of time-to-employment, starting salary levels, and vessel assignment quality? (4) What adoption barriers prevent employers from fully utilizing e-portfolio verification capabilities despite demonstrated technical advantages? (5) What hybrid transition strategies enable graduates to benefit from e-portfolios while maintaining paper documentation required by employers or regulators not yet equipped for digital credential verification?

2. RESEARCH METHOD

This study employed a mixed-methods comparative research design integrating quantitative outcome measurements with qualitative exploratory investigation to provide comprehensive assessment of e-portfolio implementation effectiveness, stakeholder adoption experiences, and career impact mechanisms in authentic maritime education and employment contexts [3]. The research design enabled systematic controlled comparison of credential verification efficiency, employer confidence levels, and career placement outcomes for STIP Jakarta graduates equipped with blockchain-enabled e-portfolios versus comparison cohorts relying on traditional paper documentation, while simultaneously exploring through qualitative inquiry the implementation challenges, adoption barriers, user experiences, and improvement recommendations that quantitative metrics alone cannot adequately capture.

2.1 Participants and Research Context

The study population comprised 261 STIP Jakarta graduates from navigation and marine engineering diploma programs across two consecutive graduation cohorts. The e-portfolio pilot cohort (n=124) included all cadets graduating during the 2023 academic year who received comprehensive digital portfolio systems during their final semester and used these systems throughout their subsequent job search and employment processes. This cohort included 71 navigation program graduates and 53 marine engineering program graduates, reflecting STIP Jakarta's typical program enrollment distribution. The traditional documentation comparison cohort (n=137) consisted of the immediately preceding 2022 graduation class who relied exclusively on conventional paper certificate documentation throughout their employment processes, including 78 navigation graduates and 59 marine engineering graduates [4].

This quasi-experimental design using naturally occurring cohorts rather than random individual assignment proved necessary given practical and ethical constraints: randomly assigning some 2023 graduates to e-portfolio systems while denying others access to potentially beneficial technology raised equity concerns; E-Portfolio Systems for Seafarer Competency Documentation: Blockchain-Enabled Digital Credentialing and Career Development Tracking (*Derma Watty Sihombing*)

mixing e-portfolio and non-e-portfolio graduates within the same cohort risked contamination effects as students might share credentials or employers might form expectations based on encountering both systems; and institutional decision-making followed cohort-level implementation patterns rather than individual assignment. Baseline equivalence testing confirmed no significant differences between cohorts in pre-graduation academic performance (e-portfolio cohort mean GPA: 3.24, SD=0.41; traditional cohort mean GPA: 3.22, SD=0.44; $t=0.34$, $p=.73$), demographic characteristics including age and gender distribution, or entry competency levels as assessed through standardized placement examinations, providing confidence that observed outcome differences reflect e-portfolio effects rather than cohort selection artifacts.

The employer participant group comprised 87 shipping companies, ship management firms, and manning agencies actively recruiting STIP Jakarta graduates during the 18-month study period. This sample included 34 Indonesian shipping companies operating domestic and regional trade routes, 28 international shipping companies with Indonesian operations recruiting Indonesian officers for global fleet deployment, and 25 manning agencies specializing in Indonesian seafarer placement with international employers. Employer participants ranged from large multinational corporations operating hundreds of vessels to small regional operators with 3-5 ships, providing representation across the diverse employer types characterizing Indonesian maritime labor markets [10].

2.1 E-Portfolio System Architecture and Features

The blockchain-enabled e-portfolio system implemented for the pilot cohort was a custom-developed platform specifically designed for maritime credentialing requirements through collaboration between STIP Jakarta's IT department, an educational technology consulting firm specializing in digital credentialing systems, and blockchain infrastructure providers. The system architecture integrated three primary technical components: institutional data integration connecting the e-portfolio platform with STIP Jakarta's existing student information system, academic records database, and training completion tracking systems to enable automated credential population without requiring manual data entry; blockchain credential verification utilizing Ethereum-based smart contracts to create cryptographically signed, tamper-proof credential records recorded on distributed ledger infrastructure accessible globally; and user interfaces including mobile applications for iOS and Android devices providing seafarer-facing portfolio management and employer-facing verification capabilities, plus web portals for desktop access and administrative functions [8].

Each graduate's digital portfolio contained comprehensive credentialing documentation: STCW certificates of competency with detailed competency domain specifications; specialized training completion certificates for mandatory and elective courses including advanced firefighting, medical care, survival craft operations, radar navigation, ECDIS, ship security, and crisis management; complete sea service records from training ship deployments documenting vessel assignments, duration, duties performed, and supervising officers; academic transcripts showing all coursework completed, grades achieved, and cumulative GPA; shipboard performance evaluations completed by training ship masters and chief engineers during sea service periods; and continuing professional development certifications for any additional workshops, seminars, or specialized training completed [11].

Blockchain verification functionality enabled one-click credential authentication: each credential record included cryptographic digital signatures created using STIP Jakarta's private key, stored as transactions on the Ethereum blockchain network, and verifiable by any party using STIP Jakarta's public key to confirm the credential was genuinely issued by the institution and had not been altered since issuance. Employers received secure verification links or QR codes from applicants that, when accessed through web browsers or verification mobile apps, automatically queried the blockchain network, retrieved the authoritative credential record, performed cryptographic hash comparison, and displayed verification results confirming authenticity, validity status, and credential details—all within seconds without requiring employer accounts, registration, or technical blockchain expertise [12].

Graduates controlled credential sharing through granular permission management interfaces enabling them to: generate secure sharing links or QR codes for specific credentials or curated credential packages relevant to particular job applications; set expiration dates for shared access ensuring employers could verify credentials during hiring processes but lost access after specified periods; track access analytics showing which employers or organizations viewed which credentials and when; and instantly revoke access if employment negotiations terminated, security concerns arose, or sharing permissions were accidentally granted [13].

2.2 Data Collection Procedures and Measurement Instruments

Credential verification efficiency was measured through multiple complementary indicators providing comprehensive assessment of verification process improvements. Verification time, the primary efficiency metric, tracked the duration from when employers requested credential verification to when they E-Portfolio Systems for Seafarer Competency Documentation: Blockchain-Enabled Digital Credentialing and Career Development Tracking (*Derma Watty Sihombing*)

received definitive confirmation of authenticity, measured in days. For traditional paper documentation, this included time for employer contact with STIP Jakarta or foreign maritime authorities, administrative processing, and response communication. For e-portfolio credentials, this measured time from when employers accessed verification links to receipt of blockchain verification results (typically seconds but measured in days for comparable units). Verification data were collected through structured employer surveys administered immediately following hiring decisions for both e-portfolio and traditional documentation job applicants.

Employer confidence in credential authenticity was assessed through validated survey instruments administered to all 87 employer participants, measuring their trust levels in credential authenticity using 5-point Likert scales (1=no confidence, 5=complete confidence) and comparing confidence ratings for e-portfolio versus traditional paper documentation. Additional survey items assessed employer satisfaction with verification processes, perceived fraud risk, and willingness to rely on credentials without additional verification [4].

Career placement outcomes were measured through comprehensive graduate employment tracking during the 18-month post-graduation period. Employment rate calculated the percentage of graduates who secured officer-level positions (third officer, second officer, or engineering equivalent) within 6 months of graduation, the standard employment timeline for maritime academy performance assessment. Time-to-employment measured days from graduation to first employment contract signing for successfully placed graduates. Starting salary levels were collected in USD for international comparability, reflecting monthly gross compensation for first officer assignments. Vessel assignment quality represented a composite indicator combining company reputation ratings, vessel condition assessments, and route desirability scores compiled from industry databases and graduate reports [5].

E-portfolio usage analytics tracked system adoption and utilization patterns including: graduate sharing frequency and patterns showing how often and in what contexts graduates shared credentials with employers; employer verification activity measuring how many employers accessed e-portfolio credentials and completed blockchain verification; credential access tracking showing which specific credentials employers most frequently requested; and system adoption rates among eligible employer populations indicating what percentage of employers actively utilized e-portfolio verification capabilities versus requesting traditional paper documentation [11].

Qualitative data collection utilized three semi-structured Focus Group Discussion (FGD) sessions designed to explore stakeholder experiences, implementation challenges, and improvement recommendations beyond what quantitative metrics could capture. The graduate FGD (n=16 participants, stratified sampling across navigation and engineering programs, employment status, and e-portfolio usage intensity) explored graduates' experiences using e-portfolios during job searches, employer reactions to digital credentials, perceived advantages and disadvantages, challenges maintaining hybrid documentation systems, and recommendations for future improvements. The employer FGD (n=12 participants, representing diverse shipping company types and sizes) examined employer perspectives on e-portfolio verification processes, integration with existing hiring workflows, perceived reliability and trustworthiness, technical barriers to adoption, and decision factors in choosing between e-portfolio and traditional verification [6].

The maritime academy administrator FGD (n=9 participants, including certification office staff, IT personnel, and academic program coordinators) explored institutional implementation experiences, technical challenges, resource requirements, support burden, stakeholder coordination issues, and strategic recommendations for other institutions considering e-portfolio adoption. All FGD sessions lasted 90-120 minutes, were conducted in Indonesian language with English technical terminology, were audio-recorded with informed consent following ethical review approval, and were transcribed verbatim for analysis [4].

2.3 Data Analysis Procedures

Quantitative data analysis utilized SPSS version 27 statistical software for all numerical analyses. Independent samples t-tests compared continuous outcome variables (verification time, confidence ratings, time-to-employment, starting salaries) between e-portfolio and traditional documentation cohorts. Chi-square tests examined categorical outcomes including employment rates and employer adoption patterns. Effect sizes were calculated using Cohen's d for continuous variables and odds ratios for categorical outcomes to assess practical significance beyond statistical significance thresholds. Statistical significance was determined using $\alpha=.05$ threshold for primary analyses with Bonferroni corrections applied for multiple comparisons [3].

Qualitative FGD data underwent systematic thematic analysis following established iterative procedures [4]. Initial data familiarization involved repeated reading of all transcripts by multiple research team members to develop comprehensive understanding of content, perspectives, and emerging patterns. Systematic open coding identified recurring concepts, specific implementation challenges, perceived advantages and barriers, user experience themes, and strategic recommendations mentioned across transcripts.

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Focused coding refined initial codes through constant comparison and aggregation into thematic categories. Theme development integrated focused codes into coherent analytical themes representing key findings, validated through independent researcher review achieving 91% inter-rater agreement with discrepancies resolved through discussion. Cross-stakeholder comparative analysis examined convergent and divergent perspectives across graduate, employer, and administrator groups.

3. RESULTS

3.1 Quantitative Findings: Verification Efficiency and Employment Outcomes

The comprehensive comparative analysis revealed that blockchain-enabled e-portfolio systems generated substantial, statistically significant, and practically meaningful improvements in credential verification efficiency and employer confidence while producing modest but significant career placement outcome gains for maritime academy graduates. These findings demonstrate e-portfolio's capacity to transform verification processes through technological innovation while simultaneously revealing that verification efficiency improvements alone do not automatically translate into proportional employment advantages given the multiple factors influencing hiring decisions beyond credential authentication.

Table 1 presents detailed comparison of credential verification efficiency and employer confidence outcomes across e-portfolio and traditional paper documentation cohorts, revealing transformative improvements in verification processes that employers utilizing e-portfolio systems experienced compared to traditional manual verification procedures.

Table 1. E-Portfolio vs. Traditional Documentation: Credential Verification Efficiency and Employer Confidence Outcomes (N=261 graduates, 87 employers)

Outcome Metric	E-Portfolio Cohort (n=124) M (SD)	Traditional Paper (n=137) M (SD)	Absolute Difference	Improvement %	Cohen's d	Significance
Verification Efficiency						
Mean Verification Time (days)	0.4 (0.3)	14.7 (6.2)	-14.3 days	-97.3%	3.84	p < .001
Verification Cost per Hire (USD)	\$12 (\$8)	\$184 (\$67)	-\$172	-93.5%	3.52	p < .001
Successful Verification Rate (%)	99.2 (2.1)	87.3 (11.4)	+11.9%	+13.6%	1.68	p < .001
Employer Confidence & Trust						
Confidence in Authenticity (1-5 scale)	4.42 (0.61)	3.04 (0.89)	+1.38	+45.4%	1.82	p < .001
Perceived Fraud Risk (1-5, lower=less risk)	1.73 (0.68)	3.26 (0.94)	-1.53	-46.9%	1.91	p < .001
Willingness to Rely Without Additional Verification (%)	91.1 (12.3)	43.8 (21.7)	+47.3%	+108.0%	2.73	p < .001
Process Satisfaction						
Overall Verification Process Satisfaction (1-5)	4.31 (0.71)	2.87 (0.96)	+1.44	+50.2%	1.73	p < .001
Verification Process Convenience (1-5)	4.56 (0.58)	2.64 (0.88)	+1.92	+72.7%	2.56	p < .001
Fraud Detection						
Credential Fraud Detection Rate (%)	0.8 (1.9)	6.2 (4.7)	-5.4%	-87.1%	1.52	p < .01

Note: Verification Time measured from employer verification request to definitive authenticity confirmation. Confidence scales: 1=very low, 5=very high. All differences statistically significant with large effect sizes ($d > 1.52$).

The 97.3 percent reduction in mean verification time from 14.7 days for traditional paper documentation to 0.4 days (approximately 10 hours, primarily reflecting time between when employers accessed verification links and when they reviewed results) for blockchain-enabled e-portfolios represents transformative efficiency improvement fundamentally altering the temporal dynamics of maritime employment hiring processes. Traditional verification procedures requiring employers to contact STIP Jakarta or Indonesian maritime authorities, wait for administrative processing, and receive verification responses through email or mail created 2-3 week delays between candidate application and final credential confirmation—delays that often extended overall hiring timelines, risked losing candidates to competing offers, or prompted employers to proceed with hiring before verification completion based on visual document inspection alone, creating fraud

vulnerabilities. E-portfolio blockchain verification enabling instant cryptographic authentication eliminated these delays entirely, enabling employers to complete comprehensive credential verification within the same business day as candidate applications, dramatically accelerating hiring processes [8].

The \$172 per-hire verification cost savings (93.5% reduction from \$184 to \$12) primarily reflects eliminated expenses that traditional verification procedures imposed on employers: international postal or courier costs for mailing certificates to authentication services or maritime authorities for verification (\$45-80 per verification); authentication service fees charged by commercial credential verification firms (\$60-90 per certificate); personnel time costs for human resource staff coordinating verification requests, follow-up communications, and documentation (\$25-40 per verification at standard HR salary rates); and contingency costs from verification failures requiring repeated attempts when authorities were unresponsive or databases were offline. E-portfolio verification costs were limited to minimal IT infrastructure for accessing verification websites and nominal internet bandwidth, creating near-zero marginal costs per verification [12].

The 11.9 percentage point improvement in successful verification rate (99.2% for e-portfolios versus 87.3% for traditional paper) reflects e-portfolio's capacity to eliminate verification failures that plagued traditional procedures: maritime authorities unreachable due to limited office hours, staff shortages, or communication infrastructure problems; verification databases offline or inaccessible; certificate information not recorded in databases due to incomplete digitization of historical records; and language barriers when verification requests crossed national boundaries requiring translation. Blockchain verification operating on continuously available global networks with cryptographic rather than administrative verification mechanisms eliminated these failure modes, enabling successful verification in virtually all cases (the 0.8% failure rate primarily reflected graduate errors in sharing credentials or employer technical difficulties accessing verification links) [13].

The 45.4 percent improvement in employer confidence in credential authenticity (4.42 versus 3.04 on 5-point scales) demonstrates that blockchain verification substantially increased employer trust in credential validity beyond what traditional paper certificates and manual verification could achieve. Employers reported that cryptographic verification providing mathematical proof of credential authenticity, combined with blockchain's tamper-proof record architecture, generated confidence levels substantially exceeding what visual security feature inspection or manual authority verification provided, given well-documented cases of sophisticated forgeries defeating visual inspection and verification failures leaving authenticity uncertain [2].

Table 2 presents career placement outcome comparisons revealing more modest but nonetheless significant employment advantages for e-portfolio-equipped graduates, indicating that verification efficiency and credential confidence improvements translate into measurable but not transformative career benefits.

Table 2. Career Placement Outcomes: E-Portfolio vs. Traditional Documentation Cohorts (N=261 graduates)

Placement Outcome Metric	E-Portfolio (n=124) M (SD)	Traditional Paper (n=137) M (SD)	Difference	% Change	Effect Size	Significance
Employment Success						
Employment Within 6 Months (%)	87.9	76.6	+11.3%	+14.8%	OR=2.18	p < .05
Employment Within 3 Months (%)	71.0	58.4	+12.6%	+21.6%	OR=1.76	p < .05
Employment Within 1 Year (%)	95.2	91.2	+4.0%	+4.4%	OR=1.89	p = .18 (ns)
Employment Timeline						
Mean Time-to-Employment (days)	67 (34)	94 (47)	-27 days	-28.7%	d=0.67	p < .01
Median Time-to-Employment (days)	58	82	-24 days	-29.3%	-	-
Compensation						
Mean Starting Monthly Salary (USD)	\$2,340 (\$420)	\$2,180 (\$490)	+\$160	+7.3%	d=0.35	p < .05
Salary Premium for E-Portfolio (%)	-	-	-	+7.3%	-	-
Employment Quality						
Vessel Assignment Quality (1-5 composite)	3.8 (0.9)	3.6 (1.0)	+0.2	+5.6%	d=0.21	p = .12 (ns)
International Employment Rate (%)	64.5	58.4	+6.1%	+10.4%	OR=1.29	p = .24 (ns)
Premium Shipping Company Employment (%)	42.7	35.8	+6.9%	+19.3%	OR=1.34	p < .05
Job Search Process						
Mean Number of Applications Submitted	8.4 (4.2)	11.7 (5.8)	-3.3	-28.2%	d=0.65	p < .01
Interview Invitation Rate (%)	68.3	52.1	+16.2%	+31.1%	-	p < .01

Note: Employment defined as securing officer-level positions. Vessel Quality composite includes company reputation, vessel condition, route desirability. OR=Odds Ratio. ns=not statistically significant. Premium companies defined as top-tier international operators.

E-portfolio graduates achieved an 87.9% employment rate within 6 months post-graduation compared to 76.6% for traditional documentation cohorts, representing an 11.3 percentage point absolute advantage and 14.8% relative improvement—a meaningful competitive edge in maritime labor markets but not the transformative employment guarantee that e-portfolio's dramatic verification improvements might theoretically enable. The employment advantage proved most pronounced during the critical first 3 months when employers make initial hiring decisions and when verification speed provides greatest competitive advantage: e-portfolio graduates achieved 71.0% employment within 3 months versus 58.4% for traditional cohorts (+12.6 percentage points, +21.6% relative improvement), suggesting that rapid credential verification enabled e-portfolio graduates to secure early employment opportunities before traditional verification delays allowed competing candidates to be fully evaluated [10].

The 27-day reduction in mean time-to-employment (67 versus 94 days, -28.7%) indicates that e-portfolio graduates secured positions substantially faster than traditional documentation cohorts on average, though with considerable individual variation as reflected in standard deviations. Median time-to-employment showed similar patterns (58 versus 82 days, -24 days, -29.3%), confirming that the mean difference was not driven by outlier cases but reflected general acceleration across the graduate population. This timeline advantage likely operates through multiple mechanisms: faster verification enabling earlier hiring decision completion; increased employer willingness to seriously consider candidates when verification is instant rather than requiring 2-3 week delays; and competitive advantages when multiple candidates are being evaluated simultaneously and faster credential confirmation enables earlier offer extension [11].

The \$160 average salary premium (\$2,340 versus \$2,180 monthly starting salaries, +7.3%) for e-portfolio graduates proved statistically significant but modest in magnitude, suggesting that e-portfolio credentials provide marginal compensation advantages but do not fundamentally transform salary negotiations. This salary differential may reflect several mechanisms: earlier employment enabling graduates to secure positions before accepting lower-paying alternatives from desperation; enhanced employer confidence enabling slightly more competitive offers; or self-selection whereby the most confident, prepared graduates most effectively utilized e-portfolio capabilities during negotiations [5].

The statistically non-significant differences in vessel assignment quality (3.8 versus 3.6 on 5-point scales, +0.2, p=.12) and international employment rates (64.5% versus 58.4%, +6.1%, p=.24) indicate that while e-portfolios accelerate employment processes and provide modest salary advantages, they do not dramatically alter the types or quality of positions graduates ultimately secure—suggesting that factors beyond credential verification including demonstrated competencies, interview performance, professional networks, and labor market conditions continue to dominate employment outcomes [1].

Table 3. E-Portfolio System Adoption and Utilization Patterns (N=124 e-portfolio graduates, 87 employers)

Adoption & Usage Metric	Value	Percentage	Notes
Graduate Adoption			
Graduates Using E-Portfolio At Least Once	121/124	97.6%	High initial adoption
Graduates Using E-Portfolio Regularly (5+ shares)	96/124	77.4%	Sustained usage
Graduates Maintaining Hybrid (E-Portfolio + Paper)	118/124	95.2%	Dual system necessity
Graduates Reporting E-Portfolio as Primary	73/124	58.9%	Increasing preference
Employer Adoption			
Employers Successfully Verifying E-Portfolio (1+ times)	52/87	59.8%	Majority adoption
Employers Regularly Using E-Portfolio Verification	38/87	43.7%	Regular users
Employers Unable/Unwilling to Use E-Portfolio	35/87	40.2%	Adoption barrier
Employers Preferring E-Portfolio Over Paper	41/87	47.1%	Growing preference
Usage Patterns			
Mean Credential Shares per Graduate	6.8	-	Active usage
Mean Employer Verifications per Graduate	4.2	-	Multiple verifications
Mean Time to First Credential Share (days post-graduation)	12	-	Rapid adoption
Credentials Shared via Mobile App (%)	-	68.3%	Mobile dominance

3.2 Qualitative Findings: Adoption Barriers and Implementation Challenges

Focus Group Discussions with graduates, employers, and maritime academy administrators revealed critical implementation challenges, adoption barriers, and user experience insights that quantitative metrics alone could not adequately capture, providing essential context for understanding why e-portfolio's dramatic technical performance advantages generated more modest employment outcome improvements and identifying strategic pathways for maximizing implementation effectiveness.

3.2.1 Digital Literacy Gaps and Employer Change Resistance

The dominant employer theme emerging from FGD analysis was "digital literacy gap and organizational change resistance"—many smaller manning agencies and traditionally-operated shipping companies lacked the IT infrastructure capacity, personnel digital skills, organizational culture, and change management capabilities necessary to integrate e-portfolio blockchain verification into established hiring workflows developed over decades around paper certificate processes. One manning agency representative articulated the challenge: "We understand intellectually that blockchain verification is more secure, faster, and reliable than our traditional phone verification procedures. But our hiring staff—many of whom have worked in seafarer recruitment for 20-30 years—are comfortable with paper certificates and verification phone calls to maritime authorities. Training everyone on new digital verification systems, updating our hiring procedures, convincing managers to trust cryptographic authentication they don't fully understand, and investing in IT infrastructure for a benefit we can't easily quantify requires organizational commitment we haven't yet prioritized given competing demands" [2].

This adoption barrier proved particularly acute among smaller maritime employers (companies operating fewer than 10 vessels, manning agencies with fewer than 50 employees) that lack dedicated IT departments, employ recruitment staff with limited technical backgrounds, and operate with minimal profit margins making any new system investment difficult to justify financially. Several employers noted that while large international shipping corporations could dedicate resources to evaluating, integrating, and training staff on e-portfolio verification, smaller operators continuing to process hiring through manual, paper-intensive workflows faced substantial switching costs despite e-portfolio's technical superiority [5].

3.2.2 Hybrid Necessity and Dual Documentation Burdens

The graduate FGD strongly emphasized the "hybrid necessity reality"—despite possessing comprehensive, blockchain-verified e-portfolios that should theoretically eliminate paper documentation needs, 95.2% of e-portfolio graduates continued maintaining complete paper certificate portfolios that they carried to job interviews, kept in protective folders during assignments, and presented to employers unable or unwilling to utilize digital credentials. This dual documentation requirement substantially reduced e-portfolio's intended administrative burden reduction benefit since graduates continued bearing all costs and efforts associated with traditional paper systems (certificate storage, organization, protection against loss/damage, physical carrying during travel) while adding e-portfolio management responsibilities on top of rather than instead of traditional documentation practices.

One navigation graduate explained: "I was excited about the e-portfolio because I thought it would mean I could stop worrying about losing my certificate book or damaging documents during travel. But in reality, I still need to maintain complete paper documentation because at least 40% of the employers I applied to either couldn't verify e-portfolio credentials technically or simply insisted on seeing physical certificates during interviews because that's what their procedures require. The e-portfolio helps with the 60% of employers who can use it—verification is faster and I can share credentials instantly—but I can't rely on it exclusively, so it becomes an additional system to manage rather than a replacement" [10].

3.2.3 Regulatory Recognition Gaps and PSC Requirements

Maritime academy administrators particularly emphasized the "regulatory recognition gap"—while e-portfolios provide cryptographically verified digital credentials that are technically superior to paper in every dimension of security and verification reliability, many port state control authorities and flag state maritime administrations have not updated their vessel inspection procedures, legal frameworks, or inspector training to accept digital documentation presented through mobile devices or web portals, continuing to require physical paper certificates during vessel inspections based on regulatory frameworks developed around paper documentation paradigms [7].

One STIP Jakarta certification office administrator explained: "We can issue perfectly secure, instantly verifiable digital credentials through blockchain that eliminate fraud risk and verification delays. But if a graduate serves aboard a vessel that gets PSC inspection in Singapore, Australia, or the U.S., and the PSC inspector asks to see their certificate of competency, they need to produce a physical paper certificate because that's what the inspection manual requires and what inspectors are trained to verify. Until IMO and regional port state control regimes formally recognize digital credentials as legally equivalent and update inspection procedures accordingly, seafarers cannot rely exclusively on e-portfolios regardless of their technical superiority—they must maintain paper certificates for regulatory compliance, making e-portfolios supplementary rather than replacement documentation" [7].

This regulatory recognition barrier operates at multiple levels: international STCW frameworks that do not explicitly address digital credentialing; national maritime regulations implementing STCW that assume paper certificate issuance; port state control memoranda of understanding that specify paper document inspection; and inspector training curricula that teach visual certificate verification techniques without addressing digital verification protocols. Until coordinated regulatory development across these levels establishes legal recognition and operational procedures for digital credentials, the regulatory constraint will persist regardless of e-portfolio technical maturity [13].

4. DISCUSSION

The research findings reveal a fundamental paradox characteristic of educational technology implementation in established professional domains: blockchain-enabled e-portfolio systems achieve transformative technical performance improvements (97.3% verification time reduction, 93.5% cost savings, 45.4% employer confidence increase) yet generate modest practical employment outcome gains (11.3 percentage point employment rate advantage, 28.7% faster placement, 7.3% salary premium) because maritime industry adoption patterns, organizational readiness levels, and regulatory framework evolution lag substantially behind technological capability advancement [5]. This pattern aligns with extensive innovation diffusion research documenting that technological superiority alone proves insufficient for widespread adoption when organizational inertia, incumbent system dependencies, regulatory path dependencies, and ecosystem coordination requirements create substantial switching costs even for demonstrably superior alternatives that would generate positive net benefits if universally adopted [5].

The employer digital literacy gap and organizational change resistance themes identified through qualitative analysis point to a fundamental implementation challenge inherent in e-portfolio deployment: digital credentialing systems optimize a specific hiring process pain point (credential verification delay and uncertainty) that employers experience as burdensome but nevertheless manageable through familiar manual workflows developed over decades, while simultaneously requiring investments in IT infrastructure procurement, personnel technical training, hiring procedure redesign, and organizational culture change that many maritime employers—particularly smaller manning agencies and traditionally-operated shipping companies dominant in Indonesian seafarer placement markets—are unprepared or unwilling to undertake given competing operational priorities, limited change management capacity, and difficulty quantifying return on investment for verification efficiency improvements [2].

Jenson and Treuer documented remarkably similar employer adoption barriers in higher education e-portfolio contexts across North American universities, noting that portfolio systems create asymmetric value propositions wherein benefits accrue primarily to credential holders (faster verification, enhanced credential security, convenient sharing) and educational institutions (reduced verification processing, enhanced credential reputation), while employers bear adoption costs (system integration, staff training, procedure modification) without receiving proportional hiring process improvements since credential verification, though undeniably faster with e-portfolios, represents a relatively small component of overall hiring timeline and decision-making compared to resume screening, interviews, reference checks, salary negotiations, and contract processing [2]. This value asymmetry creates adoption resistance whereby employers lack compelling business cases for investment despite the systemic efficiency gains that widespread adoption would generate.

The hybrid necessity phenomenon—wherein 95.2% of e-portfolio graduates maintained complete paper documentation systems parallel to digital portfolios—represents an especially consequential adoption barrier because it prevents realization of e-portfolio's intended administrative burden reduction benefit. E-portfolio proponents envision digital credentials replacing paper entirely, eliminating certificate loss risks, storage requirements, and physical carrying burdens. However, when graduates must maintain both systems to accommodate the 40% of employers unable or unwilling to use digital verification, e-portfolios become an additional documentation layer rather than a simplifying replacement, actually increasing rather than decreasing administrative overhead during the transitional adoption period [10]. This dual-system burden may persist for years or even decades as industry adoption gradually expands, creating long-term costs that may discourage sustained e-portfolio utilization particularly among graduates who experience limited employer acceptance.

The regulatory recognition gap represents perhaps the most fundamental barrier requiring policy intervention beyond any individual institution's control [7]. Blockchain-enabled digital credentials can achieve technical perfection—cryptographically tamper-proof, instantly verifiable globally, impossible to forge, more secure than any paper certificate with security features—yet remain legally and practically inferior if port state control inspectors cannot or will not accept them during vessel inspections because regulatory frameworks have not been updated to recognize digital formats as equivalent to traditional certificates for compliance verification purposes. As one administrator noted, "We can build the world's best e-portfolio system, but if PSC inspectors in major port states continue requiring paper certificates, our graduates must carry paper regardless of how good the digital system is."

This points to the critical need for coordinated international maritime regulatory development establishing legal frameworks and operational procedures for digital seafarer credentials [7]. The IMO's ongoing work through its Facilitation Committee on developing digital maritime documentation standards, including potential amendments to STCW frameworks explicitly accommodating digital credentialing, represents essential enabling infrastructure for e-portfolio widespread adoption. However, IMO's characteristically deliberate consensus-based regulatory development process—typically requiring 5-10 years from initial proposal through convention amendment, member state ratification, and entry into force—means that international regulatory recognition represents a long-term rather than near-term adoption enabler. National-level regulatory development through individual flag states amending domestic maritime regulations to recognize digital credentials could proceed faster but creates fragmentation risks where Indonesian maritime authorities might recognize digital credentials for Indonesian-flagged vessels while other flag states continue requiring paper, limiting utility for Indonesian seafarers seeking international employment [13].

Port state control memoranda of understanding (Paris MOU, Tokyo MOU, Indian Ocean MOU) representing regional port state cooperation frameworks would need to coordinate inspection procedure updates, inspector training curriculum modifications, and detention policy adaptations to effectively operationalize digital credential recognition even after formal regulatory frameworks are established. The multi-level, multi-jurisdictional coordination required across IMO, flag states, and regional PSC regimes creates substantial coordination complexity that likely explains why regulatory recognition has not kept pace with technological development despite e-portfolio pilot implementations dating back over a decade in various educational contexts [8].

The modest employment outcome improvements (11.3 percentage point employment rate advantage, 28.7% faster placement) despite dramatic verification efficiency gains require careful interpretation regarding e-portfolio's employment value proposition. Two competing interpretations merit consideration. The optimistic interpretation holds that an 11.3 percentage point employment advantage represents genuinely consequential career benefits for graduates in competitive maritime labor markets where even small advantages can determine employment success versus extended unemployment, and that 28.7% faster placement (27 days on average) provides meaningful financial and psychological benefits during job search periods. Under this interpretation, e-portfolios provide valuable employment advantages even if not transformative, and the modest magnitude reflects realistic expectations that credential verification is one among many hiring factors (competency demonstration, interview performance, salary expectations, network connections, industry conditions) influencing employment outcomes [1].

The skeptical interpretation holds that an 11.3 percentage point advantage may partly reflect selection effects—more motivated, organized, technologically adept graduates who most effectively utilized e-portfolio capabilities may have achieved higher employment rates even without e-portfolios through other advantages they possess—and that employment rate differences within the first 6 months may disappear over longer timeframes as traditionally-documented graduates eventually secure employment despite slower verification. The statistically non-significant difference in 1-year employment rates (95.2% versus 91.2%, $p=.18$) provides some support for this interpretation, suggesting that e-portfolios accelerate employment timing without fundamentally altering eventual employment probability [11]. Longitudinal research tracking graduates over multi-year periods and controlling for individual characteristics through propensity score matching or instrumental variable approaches could adjudicate between these interpretations.

Several study limitations warrant acknowledgment and suggest directions for future research. The quasi-experimental design with cohort-level assignment rather than individual randomization, while necessary given practical and ethical constraints, creates potential selection bias risks despite baseline equivalence testing showing no significant pre-graduation differences. Unmeasured cohort differences in motivation, labor market conditions, or employer hiring patterns could potentially confound e-portfolio effect estimates. Future research employing randomized controlled trial designs where feasible, or quasi-experimental methods with more sophisticated confounder adjustment, would strengthen causal inference.

The single-institution focus on STIP Jakarta limits generalizability to other maritime education contexts with different graduate populations, employer networks, technological infrastructure, or institutional capabilities. Future research should examine e-portfolio implementation across multiple Indonesian maritime academies including private institutions, across Southeast Asian maritime education systems with varying regulatory frameworks and industry structures, and in developed country contexts where employer digital readiness may differ substantially. The 18-month post-graduation follow-up period, while longer than most educational technology studies, remains relatively short for assessing career trajectory impacts. Multi-year longitudinal research tracking graduates through career advancement, specialization development, and lifetime earnings would provide more comprehensive outcome assessment.

5. CONCLUSION

This mixed-methods comparative study demonstrates that blockchain-enabled e-portfolio systems achieve dramatic credential verification efficiency improvements (97.3% time reduction from 14.7 to 0.4 days, 93.5% cost savings, 87.1% fraud detection improvement) and substantial employer confidence gains (45.4% increase in authenticity confidence) while generating modest but meaningful career placement outcome improvements for maritime academy graduates (11.3 percentage point employment rate advantage, 27 days faster placement, 7.3% salary premium) relative to traditional paper documentation systems. However, significant industry adoption barriers including employer digital literacy gaps, limited IT infrastructure among smaller maritime operators, organizational change resistance, and regulatory recognition deficits substantially constrain practical benefit realization despite compelling technical advantages. The persistent hybrid documentation necessity—95.2% of e-portfolio graduates maintaining complete paper systems parallel to digital portfolios—prevents achievement of intended administrative burden reduction benefits and may discourage long-term sustained utilization. Maritime education institutions should pursue e-portfolio implementation through phased, pragmatic approaches incorporating industry partnership development cultivating employer verification capacity, regulatory engagement advancing digital credential legal recognition through national authorities and IMO frameworks, hybrid transition strategies acknowledging multi-year adoption timelines, and employer capacity building programs addressing digital literacy and change management barriers essential for maximizing implementation effectiveness.

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