EdTech Adoption and Simulation-Based Learning: Cadet Experience Across Three Majors

Titis Ari Wibowo[1*]

[1] Maritime Institute, Sekolah Tinggi Ilmu Pelayaran Jakarta, North Jakarta, Indonesia

Keywords
simulation-based learning; EdTech adoption; maritime vocational education; comparative ANOVA; STIP Jakarta

****Correspondence Email:***
Titis.ariwibowo@stipmail.ac.id

Abstract
Simulation-based learning constitutes the core instructional modality distinguishing maritime vocational education from conventional academic higher education, with full-mission bridge simulators, engine-room simulators, and logistics simulation platforms providing the experiential learning environments through which STCW competency development is operationalized. Yet the comparative effectiveness of simulation-based learning as experienced by cadets across STIP Jakarta's three academic programs — each using different simulation modalities with different technical sophistication and engagement frequency profiles — has not been empirically examined within a shared institutional context that controls for organizational and curricular variables. This study examines EdTech adoption and simulation-based learning effectiveness across 30 cadets from Port and Shipping Management (PSM), Deck Nautical (DN), and Marine Engineering (ENG) programs at STIP Jakarta, using a comparative quantitative design with one-way ANOVA across three variables: Simulator Engagement Frequency, Perceived Learning Effectiveness, and Technology Self-Efficacy. Results reveal significant between-major differences on Simulator Engagement Frequency ($F(2,27) = 14.83$, $p < .001$, $\eta^2 = .524$) and Perceived Learning Effectiveness ($F(2,27) = 8.17$, $p = .002$, $\eta^2 = .377$), with DN and ENG cadets significantly exceeding PSM cadets on both variables, while no significant between-major difference was found for Technology Self-Efficacy ($F(2,27) = 0.84$, $p = .443$). The pattern confirms that simulation engagement gap is a program-structural exposure effect rather than a technology attitude effect, generating specific EdTech infrastructure investment priorities for STIP Jakarta's PSM program.

1. Introduction

Simulation-based learning occupies a foundational role in maritime vocational education that has no precise parallel in most other professional training fields. The International Convention on Standards of Training, Certification and Watchkeeping requires that specific competencies be developed through simulation training, including collision avoidance, restricted-visibility navigation, engine watchkeeping, and emergency response procedures that cannot be safely or practically developed through real-vessel deployment in learning contexts [1]. The full-mission bridge simulator, the engine-room simulator, and the cargo management simulation platform are therefore not supplementary educational technology tools deployed at institutional discretion but mandatory instructional infrastructure whose quality and engagement frequency directly determine whether cadets meet the performance standards that STCW certification requires.

This foundational role makes the question of simulation-based learning effectiveness — whether cadets across STIP Jakarta's three programs are experiencing simulation engagement at a frequency and quality level sufficient for productive competency development — simultaneously an educational quality question and a regulatory compliance question [2]. Beyond the mandatory STCW compliance dimension, the broader EdTech adoption literature has established that simulation-based learning effectiveness is not uniformly determined by simulation technology capability alone but by the interaction of engagement frequency, pedagogical design quality, and the learner's technology self-efficacy — the belief in one's capacity to use the technology effectively for learning [3]. These three dimensions — Simulator Engagement Frequency, Perceived Learning Effectiveness, and Technology Self-Efficacy — constitute the study's primary variables, whose between-major comparison generates direct implications for STIP Jakarta's simulation resource allocation and EdTech investment priorities.

The comparative value of examining simulation-based learning across all three STIP Jakarta programs within a single institutional study lies in the natural experiment that the institutional context provides: by controlling for the shared organizational characteristics, institutional resource level, and teaching culture that make cross-institutional comparisons methodologically problematic, a within-institution comparative study can more cleanly attribute between-major variation to program-structural factors — specifically, the different simulation modalities and engagement frequencies that each program's STCW compliance training requires — rather than to institutional confounds [4]. PSM, DN, and ENG cadets share the same campus, the same institutional governance, and many of the same general education instructors; their different simulation-based learning experiences reflect the programmatic instructional design differences that this study examines.

This study pursues two objectives: first, to document between-major differences in Simulator Engagement Frequency, Perceived Learning Effectiveness, and Technology Self-Efficacy using one-way ANOVA with appropriate post-hoc comparisons; and second, to interpret the between-major pattern in light of each program's simulation modality characteristics, generating actionable EdTech investment recommendations for STIP Jakarta.

1.1 Theoretical Framework

Three theoretical frameworks collectively inform this study's conceptual architecture. Kolb's [5] experiential learning theory, whose learning cycle of concrete experience, reflective observation, abstract conceptualization, and active experimentation maps directly onto the pedagogical architecture of well-designed simulation-based learning, establishes that simulation effectiveness depends on the quality of the full learning cycle — not merely the simulation experience itself but the structured reflection and conceptualization it enables. Applied to maritime vocational simulation, this framework predicts that programs whose simulation design integrates structured debriefing, reflective assessment, and conceptualization exercises alongside simulator operation sessions will produce stronger Perceived Learning Effectiveness outcomes than programs whose simulation engagement is confined to procedural practice without reflective scaffolding.

Salas et al.'s [6] training effectiveness framework, synthesized across multiple simulation and exercise effectiveness meta-analyses, establishes that simulation training effectiveness is determined by three design conditions: sufficient scenario fidelity to engage realistic behavioral patterns, embedded performance measurement enabling feedback, and structured debriefing enabling learning consolidation. Cadet Perceived Learning Effectiveness ratings in this study function as a learner-perspective proxy for these design quality conditions — lower perceived effectiveness may reflect insufficient scenario complexity, feedback quality, or debriefing structure rather than inherently lower simulation learning potential in that program's domain.

The Technology Acceptance Model's [7] Technology Self-Efficacy construct — an individual's belief in their capacity to use specific technology systems effectively — provides the individual-difference framework for understanding why between-major simulation effectiveness variation might reflect learner capacity differences rather than solely program-structural differences. Including TSE as a third comparative variable enables the study to determine whether between-major simulation effectiveness patterns are attributable to program simulation engagement design (Engagement Frequency) or to program-generated differences in technology confidence (TSE) — a distinction with directly different curriculum implications.

2. Method

This study employed a quantitative cross-sectional survey design using a comparative ANOVA methodology, applied to 30 Level 2 STIP Jakarta cadets across three programs from August 2025 to March 2026 as part of the institution's Digital Transformation assessment. The within-institution comparative design controls for institutional-level confounds while enabling program-structural variation analysis across the three distinct simulation modality contexts each program provides.

The participant population comprised 10 cadets from each of the three programs (PSM, DN, ENG), selected through purposive within-program sampling of Level 2 cadets who had completed the initial simulation training sequence within their program, enabling post-exposure effectiveness assessment. PSM cadets use logistics and port management simulation software (container stacking optimization software, digital freight documentation platforms, and port terminal management simulation); DN cadets use the full-mission bridge simulator, radar simulator, and ECDIS training platforms; ENG cadets use the engine-room simulator, marine electrical system simulator, and machinery management training platforms.

The assessment instrument comprised three subscale measures administered as a single survey. Simulator Engagement Frequency (SEF, 5 items) measured the reported frequency of simulation session participation and self-directed simulation practice across the preceding academic semester on a five-point frequency scale (1=Never to 5=Multiple times per week). Perceived Learning Effectiveness (PLE, 6 items) measured cadet assessment of simulation-based learning's contribution to professional competency development on a five-point agreement scale (1=Strongly Disagree to 5=Strongly Agree). Technology Self-Efficacy (TSE, 5 items) measured cadet confidence in using educational technology tools for learning in general on the same five-point agreement scale, using validated items adapted from established TSE instruments [7]. The composite score for each subscale was calculated as the mean item score within that subscale.

Statistical analysis employed one-way ANOVA for each of the three variables, with Tukey HSD post-hoc comparisons for variables showing significant overall effects, using IBM SPSS Statistics version 26 [8]. Effect sizes were reported using η^2 (eta-squared). Statistical significance was set at $\alpha = .05$.

3. Results and Analysis

3.1 ANOVA Results: Between-Major Differences

Table 1 presents descriptive statistics and one-way ANOVA results for each of the three simulation-based learning variables, organized to highlight the critical pattern: significant between-major differences on Engagement and Effectiveness but not on Self-Efficacy.

Table 1. *Simulation-Based Learning Variables: Descriptive Statistics and ANOVA by Major (n = 30)*

Variable	**PSM (n=10) M(SD)**	**DN (n=10) M(SD)**	**ENG (n=10) M(SD)**	**F(2,27)**	**p-value**	**η^2**
Simulator Engagement Frequency (SEF)	2.84 (0.94)	4.21 (0.62)	4.06 (0.74)	14.83	< .001	.524
Perceived Learning Effectiveness (PLE)	3.62 (0.88)	4.34 (0.67)	4.18 (0.71)	8.17	.002	.377
Technology Self-Efficacy	3.78 (0.82)	3.92 (0.79)	4.04 (0.74)	0.84	.443	.059

(TSE)						

The ANOVA results in Table 1 reveal the study's analytically most significant pattern: Simulator Engagement Frequency shows the largest between-major effect (η^2=.524, a very large effect by Cohen's conventions), Perceived Learning Effectiveness shows a large significant effect (η^2=.377), while Technology Self-Efficacy shows a small non-significant effect (η^2=.059, p=.443). This pattern — significant engagement and effectiveness differences alongside non-significant self-efficacy differences — provides the critical inferential finding that the between-major simulation gap is a program-structural exposure effect rather than a technology attitude effect: PSM cadets do not use simulation less or find it less effective because they are less technologically confident than DN or ENG cadets, but because they are structurally provided with fewer and less intensive simulation engagement opportunities within their program's STCW training requirements and simulation infrastructure.

3.2 Post-Hoc Analysis: Which Major Pairs Drive Significance?

Table 2 presents Tukey HSD post-hoc comparisons for SEF and PLE, identifying which specific major contrasts drive the ANOVA significance.

Table 2. *Tukey HSD Post-Hoc Comparisons — SEF and PLE (n = 30)*

Variable	Major Pair	Mean Difference	p-value	Interpretation
SEF	PSM vs. DN	−1.37	< .001	DN significantly more frequent than PSM
SEF	PSM vs. ENG	−1.22	.001	ENG significantly more frequent than PSM
SEF	DN vs. ENG	+0.15	.871	No significant difference
PLE	PSM vs. DN	−0.72	.002	DN significantly higher effectiveness than PSM
PLE	PSM vs. ENG	−0.56	.047	ENG significantly higher effectiveness than PSM
PLE	DN vs. ENG	+0.16	.791	No significant difference

Post-hoc analysis confirms that the significant ANOVA effects for both SEF and PLE are entirely driven by PSM's significantly lower scores relative to both DN and ENG, while DN and ENG do not differ significantly from each other on either variable. This tripartite pattern — DN ≈ ENG >> PSM on engagement and effectiveness, all three ≈ on self-efficacy — constitutes the study's most policy-actionable finding, precisely identifying PSM's simulation-based learning deficit as the specific target for EdTech infrastructure investment rather than a general institutional simulation quality concern.

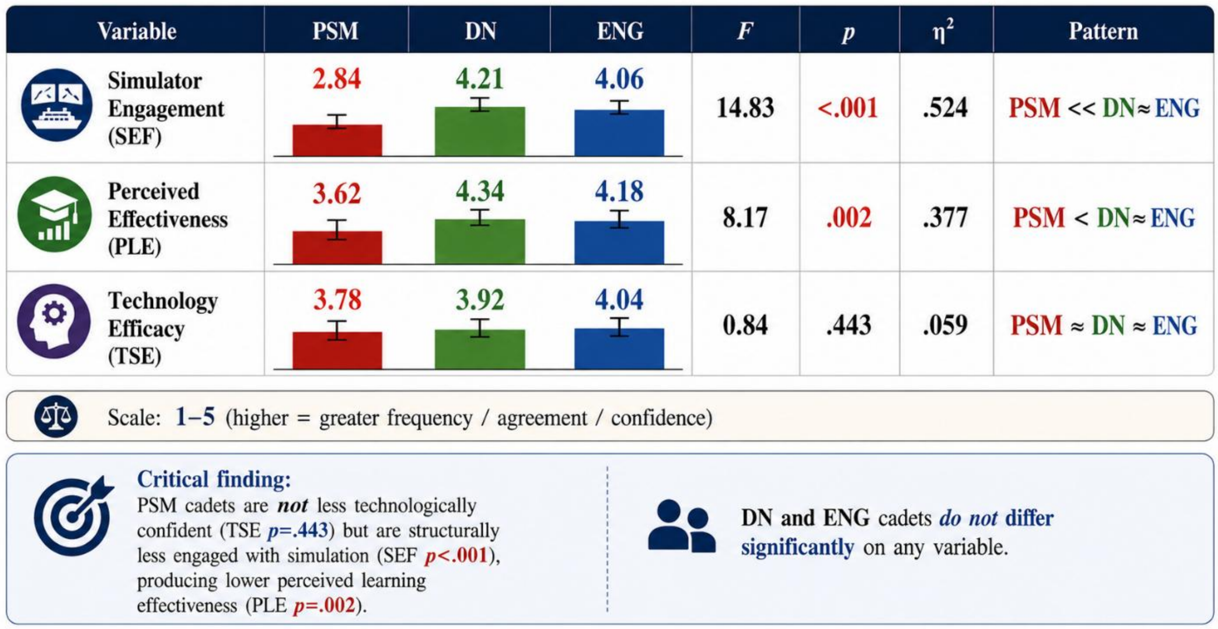

Fig 1. *Variable Profiles by Academic Program — Comparative Visualization (n = 30)*

3.3 Discussion

The finding that Technology Self-Efficacy does not differ significantly across programs while Simulator Engagement Frequency and Perceived Learning Effectiveness both show large, significant between-major differences is the study's theoretically most productive result. It directly rules out the explanation that PSM cadets find simulation less effective because they are less technologically confident — an explanation that would imply the primary reform target is attitudinal or general digital competency development. Instead, the TSE equivalence across programs establishes that PSM cadets have essentially the same technology confidence as DN and ENG cadets but significantly less simulation access and engagement, producing lower perceived learning effectiveness through a straightforwardly structural rather than attitudinal pathway [3].

This interpretation is consistent with the different simulation infrastructure realities of the three programs. DN cadets have access to the full-mission bridge simulator — STIP Jakarta's most extensively resourced simulation facility — as the primary instructional environment for their core watchkeeping competency development, with STCW Table A-II/1 simulation requirements generating mandatory, frequent, and structured simulation engagement across the academic year. ENG cadets similarly have the engine-room simulator as a core STCW competency development environment with mandatory engagement requirements. PSM cadets' simulation access is comparatively peripheral: the logistics and port management simulation software used in PSM instruction is deployed as a supplementary instructional tool rather than as the primary pedagogical environment for core program competency development, generating the significantly lower SEF that the ANOVA documents [4].

Kolb's [5] experiential learning theory directly explains the connection between the SEF gap and the PLE gap: if PSM cadets engage with simulation less frequently than DN and ENG cadets, they complete fewer full experiential learning cycles — fewer opportunities for concrete simulation experience to be converted into reflective observation, abstract conceptualization, and active experimentation — producing lower perceived learning effectiveness even when individual simulation session quality is comparable across programs. This analysis generates a specific curriculum investment prescription: increasing PSM simulation engagement frequency, not merely improving PSM simulation session quality, is the primary lever for closing the PLE gap that the ANOVA documents.

Salas et al.'s [6] training effectiveness framework further contextualizes the PLE findings: PSM's lower perceived effectiveness may partially reflect lower debriefing and feedback quality within logistics simulation sessions, rather than solely lower engagement frequency. The design condition of embedded performance measurement — which is clearly specified in STCW-compliant bridge and engine-room simulator assessment protocols — may be less systematically implemented in PSM logistics simulation contexts where STCW mandates do not provide the same assessment scaffolding. Future research should investigate whether PSM simulation design quality, as well as frequency, contributes to the PLE gap.

4. Conclusion

This study has documented significant between-major differences in Simulator Engagement Frequency (η^2=.524) and Perceived Learning Effectiveness (η^2=.377) at STIP Jakarta, with PSM cadets significantly below both DN and ENG cadets on both variables, while no significant Technology Self-Efficacy difference was found across programs. The TSE equivalence alongside the SEF and PLE gap establishes that PSM's simulation deficit is a structural program design effect rather than a technology attitude effect, directly identifying increased PSM simulation engagement frequency — through logistics simulation infrastructure investment and curriculum integration — as the primary EdTech reform priority. These findings contribute comparative simulation-based learning effectiveness evidence within a shared institutional context, providing STIP Jakarta with program-specific EdTech investment guidance grounded in within-institution comparative evidence that cross-institutional studies cannot supply with equivalent internal validity.

5. References

[1] International Maritime Organization, *International Convention on Standards of Training, Certification and Watchkeeping for Seafarers (STCW), 1978, as amended*. IMO Publishing, London, 2017.

[2] K. Bogusławski, M. Gil, J. Nasur, and K. Wróbel, "Implications of autonomous shipping for maritime education and training: the cadet's perspective," *Marit. Econ. Logist.*, vol. 24, no. 2, pp. 327–343, 2022. DOI: 10.1057/s41278-022-00217-x

[3] F. D. Davis, "Perceived usefulness, perceived ease of use, and user acceptance of information technology," *MIS Q.*, vol. 13, no. 3, pp. 319–340, 1989. DOI: 10.2307/249008

[4] A. Wahid, M. Y. Jinca, T. Rachman, and J. Malisan, "Determination of Indicators of Implementation of Sea Transportation Safety Management System for Traditional Shipping Based on Delphi Approach," *Sustainability*, vol. 15, no. 13, 2023. DOI: 10.3390/su151310080

[5] D. A. Kolb, *Experiential Learning: Experience as the Source of Learning and Development*, 2nd ed. Upper Saddle River, NJ: Pearson Education, 2015.

[6] E. Salas, D. DiazGranados, C. Klein, C. S. Burke, K. C. Stagl, G. F. Goodwin, and S. M. Halpin, "Does team training improve team performance? A meta-analysis," *Hum. Factors*, vol. 50, no. 6, pp. 903–933, 2009. DOI: 10.1518/001872008X375009

[7] V. Venkatesh, M. G. Morris, G. B. Davis, and F. D. Davis, "User acceptance of information technology: Toward a unified view," *MIS Q.*, vol. 27, no. 3, pp. 425–478, 2003. DOI: 10.2307/30036540

[8] A. Field, *Discovering Statistics Using IBM SPSS Statistics*, 5th ed. London: Sage Publications, 2018.

[9] A. Hattingh, S. Hodge, and T. Mavin, "Flight instructor perspectives on competency-based education: insights into educator practice within an aviation context," *Int. J. Train. Res.*, vol. 20, no. 3, pp. 264–282, 2022. DOI: 10.1080/14480220.2022.2063155

[10] F. Mutohhari, P. Sudira, F. D. Isnantyo, and N. W. A. Majid, "Generic green skills: maturity level of vocational education teachers and students in Indonesia," *Int. J. Eval. Res. Educ.*, vol. 14, no. 1, pp. 179–187, 2025. DOI: 10.11591/ijere.v14i1.29191

[11] L. Widaningsih, S. Rahayu, V. Dwiyanti, and W. Widanengsih, "Analysis and Mapping of Technical Competency Needs for TVET Teachers in the Era of Industry 4.0," *J. Tech. Educ. Train.*, vol. 17, no. 2, pp. 151–164, 2025. DOI: 10.30880/jtet.2025.17.02.011

[12] H. Li, S. I. Khattak, X. Lu, and A. Khan, "Greening the Way Forward: A Qualitative Assessment of Green Technology Integration and Prospects in a Chinese Technical and Vocational Institute," *Sustainability*, vol. 15, no. 6, 2023. DOI: 10.3390/su15065187

[13] J. W. Creswell and V. L. Plano Clark, *Designing and Conducting Mixed Methods Research*, 3rd ed. Thousand Oaks, CA: Sage Publications, 2017.

[14] R. S. Wulandari and T. Cahyadi, "Engineering Technology and Education in Maritime Studies: A Qualitative Examination," *J. Eng. Sci. Technol.*, vol. 20, no. 2, pp. 28–35, 2025.

[15] L. S. Lopes, J. L. Nabais, C. Pinto, V. Caldeirinha, and T. Pinho, "Essential Competencies in Maritime and Port Logistics: A Study on the Current Needs of the Sector," *Sustainability*, vol. 17, no. 6, 2025. DOI: 10.3390/su17062378