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MODERNIZING CLASSROOMS THROUGH SMART BOARDS: LEARNING EFFECTIVENESS IN MARITIME VOCATIONAL HIGHER EDUCATION WITH LEARNING EXPERIENCES

Jarot Delta Susanto[1a*], Sursina[2b], Hartaya[3c], Titis Ari Wibowo[4d], Nurindah Dwiyani[5e]

[12345]Maritime Institute, Sekolah Tinggi Ilmu Pelayaran Jakarta Jl. Marunda Makmur, Cilincing, North Jakarta, Indonesia

[a]*E-mail: rizkireva08@gmail.com*
[b]*E-mail: oktarizka.r.adneg@upnjatim.ac.id*
[c]*E-mail: hartayastip@gmail.com*
[d]*E-mail: titisariwibowo37@gmail.com*
[e]*E-mail: nurindah05kammar@gmail.com*

(*) Corresponding Author
jardelster@gmail.com

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ABSTRACT

In the present study, the influence of Smart Board technology on learning effectiveness of learning processes in maritime vocational higher education institution where the effective visualization of theoretical training is an essential requirement before practical training on simulators is being examined. The study aims to investigate the influence of Smart Board application directly and indirectly on the learning effectiveness and students' learning experience respectively. For the purpose of the study, a quantitative cross-sectional causal-correlational research design was employed through surveying 125 active diploma undergraduate students from Jakarta Maritime Higher Education Institution. The participants of the study were selected through purposive sampling method since of their direct exposure to Smart Board use. The application of Smart Board has been found to significantly affect the learning effectiveness ($\beta = 0.476$, $p < 0.001$, $f^2 = 0.360$) and the learning experiences of students ($\beta = 0.630$, $p < 0.001$, $f^2 = 0.658$). Furthermore, learning experiences have a significant effect on learning effectiveness ($\beta = 0.396$, $p < 0.001$, $f^2 = 0.250$). Furthermore, learning experience plays a role as mediator for the relationship between the use of Smart Board and learning effectiveness ($\beta = 0.250$, $p < 0.001$, VAF = 34.4%). The model explains 62.1% of variance in learning effectiveness ($R^2 = 0.621$). Hence, it is concluded that use of Smart Board affects the learning effectiveness of students both directly and mediately.

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INTRODUCTION

The modernization of the classroom environment has become one of the major priorities in higher education due to the integration of interactive digital technologies, which are aimed at improving the quality of the learning process and

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increasing its efficiency. With the help of technologies like interactive digital whiteboards and smart classrooms, it is possible for teachers to work with multimedia information and visualize complicated ideas, conduct collaborative tasks and interact with students in real time. Research shows the potential of educational technologies for improving the results and engaging the attention of students (Made et al., 2025; Priyatna et al., 2022). Nevertheless, the impact that they can provide depends not only on the availability of these technologies but also on the integration process and learning experience provided by technology.

This issue is particularly relevant in maritime vocational higher education, where theoretical instruction provides the foundation for subsequent simulator-based and field-based training. Maritime students must understand complex concepts related to navigation, ship stability, marine engineering, and safety before applying them in practical environments. Effective visualization, interaction, and conceptual understanding are therefore important for preparing students to develop professional competencies in accordance with international maritime competency requirements (Ardana et al., 2023; Ng & Chu, 2021). Furthermore, technological developments in the maritime industry, including the emergence of autonomous ships, continue to transform operational practices and competency requirements (Caroline & Hanafi, 2024; Hwang et al., 2021). These developments reinforce the need for maritime higher education institutions to provide effective theoretical instruction that prepares students to adapt to increasingly sophisticated maritime technologies.

Notwithstanding the increasing number of studies on educational technology, empirical evidence regarding the role of interactive digital whiteboards in maritime vocational higher education remains limited. Previous studies have primarily examined educational technologies, smart classrooms, and technology adoption in conventional academic settings, where theoretical learning is not necessarily followed by specialized simulator training (Anggraeni et al., 2020; Made et al., 2025). In contrast, maritime vocational education requires students to connect abstract theoretical knowledge with highly technical practical competencies. This distinctive context raises questions about whether Smart Board technology can effectively support theoretical learning before students progress to simulator-based and field-based training.

Furthermore, prior studies have mainly concentrated on the relationship that exists between technology usage and learning achievements, with comparatively less attention given to the mechanisms through which technology contributes to learning effectiveness. Specifically, the mediating role of students' learning experiences remains insufficiently explored. The availability of Smart Board technology does not necessarily guarantee improved learning outcomes because its educational value may depend on whether it facilitates meaningful interaction, active engagement, and deeper understanding. Therefore, examining students' learning experiences as a potential mediating variable can provide a more comprehensive explanation of how technology-supported instruction contributes to learning effectiveness. This gap provides the basis for investigating both the direct relationship between Smart Board utilization and learning effectiveness and the indirect relationship operating through students' learning experiences.

The relationship between Smart Board utilization, students' learning experiences, and learning effectiveness can be explained through Constructivist Learning Theory and Experiential Learning Theory. Constructivist learning theory stresses that knowledge is constructed through interaction, representation, and collaboration. In this respect, Smart Boards can support knowledge construction by enabling dynamic visualizations, multimedia presentations, and interactive classroom activities. These features may encourage students to engage actively with learning materials rather than passively receive information through conventional lectures. By facilitating the representation and discussion of complex concepts, Smart Boards may also help students connect new information with their existing knowledge.

Experiential Learning Theory further explains that meaningful learning develops through active engagement with experiences and reflection on those experiences (Kolb & Kolb, 2022). In maritime vocational education, Smart Boards can function as a cognitive and visual bridge between abstract theoretical concepts and practical simulation activities. Interactive representations may help students develop conceptual understanding before encountering more complex simulator-based situations. Although classroom-based Smart Board activities do not replace direct practical experience, they can provide an instructional foundation which encourages students subsequent engagement with simulations and field-based training. Accordingly, more meaningful learning experiences are expected to contribute to greater learning effectiveness, including improved comprehension, knowledge retention, collaborative problem-solving, and critical thinking (Firdaus & Heikal, 2024).

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Building on these theoretical perspectives, the present study conceptualizes students' learning experiences as a mechanism through which Smart Board utilization may contribute to learning effectiveness. Smart Board utilization is expected to influence learning effectiveness directly by supporting the presentation and understanding of theoretical material. It may also influence learning effectiveness indirectly by facilitating more interactive, engaging, and meaningful learning experiences. In this framework, learning experiences represent the process through which instructional technology may be translated into educational outcomes. This perspective moves beyond the assumption that technology availability alone produces better learning outcomes and instead emphasizes the importance of students' engagement with technology-supported instructional activities.

The study focuses on the institutional use of Smart Boards in physical classrooms at the Jakarta Maritime Higher Education Institute, rather than on emergency remote learning or technology-related challenges associated with unstable internet connectivity (Al-Emran et al., 2020; Setiadi & Bramastia, 2021). This setting provides a relevant context for examining classroom modernization as part of theoretical maritime instruction before students enter simulator-based practical training. The distinction between classroom and simulation technologies is important because they serve different but interconnected instructional functions. While sophisticated simulators provide realistic environments for practicing maritime operations, Smart Boards can support the conceptual preparation necessary for students to understand and interpret the situations encountered during practical training. Therefore, Smart Board utilization is positioned as a complementary instructional approach rather than a substitute for simulation-based or field-based learning.

The main objective of the current research is based on the stated research gap and theoretical framework to analyze the influence of Smart Board usage on learning effectiveness in maritime vocational higher education, and the mediating role of students' learning experience in this relationship. The following relations will be examined in this study: the influence of Smart Board usage on learning effectiveness, the influence of Smart Board usage on students' learning experience, the influence of students' learning experience on learning effectiveness.By examining these relationships simultaneously, the study seeks to clarify both the direct contribution of Smart Board utilization and its potential indirect contribution through students' learning experiences.

The key contributions of this research paper include examining students' learning experiences as a mediating mechanism between Smart Board utilization and learning effectiveness within the specialized context of maritime vocational higher education. Theoretically, the study integrates Constructivist Learning Theory and Experiential Learning Theory to explain how interactive classroom technology may support knowledge construction and meaningful learning experiences. Empirically, it extends previous research beyond the direct technology-to-outcome relationship by examining the experiential mechanism underlying this relationship in an educational setting characterized by the integration of theoretical instruction and specialized practical training. Practically, The results are anticipated to give guidelines for educators and institutions in creating technology-supported maritime learning environments that strengthen conceptual understanding, student engagement, and learning effectiveness before students proceed to simulator-based and field-based practice.

METHOD

This study employed an empirical quantitative survey design administered between September and November 2025 at the Jakarta Maritime Higher Education Institute, adhering to institutional ethical guidelines with informed participant consent. The target population comprised active undergraduate cadets enrolled in semesters 2, 4, 7, and 8 across AZZ and experiential learning. Construct indicators comprised four items for Smart Board Utilization (*SB1–SB4* measuring visual interactivity, multimedia integration, dynamic explanation, and classroom engagement), four items for Students' Learning Experiences (*PB1–PB4* measuring active participation, conceptual comprehension, motivation, and interactive collaboration), and three items for Learning Effectiveness (*EP1–EP3* measuring academic achievement, task completion efficiency, and learning outcome quality).

Although the structural equation modeling framework evaluates directional path coefficients, the cross-sectional and non-experimental research design necessitates cautious interpretation, framing the findings primarily in terms of predictive and associational relationships rather than definitive clinical causality. This causal-correlational architecture allows researchers to examine structural dependencies and mediating mechanisms among existing latent variables without

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experimental manipulation (Garson, 2016). Consequently, while statistical hypotheses test directional influences, the resulting coefficients reflect robust predictive associations within a specific temporal window, mitigating overclaims of absolute causation and acknowledging the necessity for future longitudinal or experimental verification (Hair, Hult, Ringle, Sarstedt, et al., 2021).

The target population consisted of active students registered in the Diploma IV programs at the Jakarta Maritime Higher Education Institute. Using purposive sampling, the inclusion criteria required participants to be active students in semesters 2, 4, 7, and 8 who had completed at least one semester of Smart Board-integrated theoretical instruction. Semester 6 cadets were excluded because they were undertaking mandatory sea-going cadetship (*Praktik Laut*) during the data collection period and therefore were unavailable for classroom-based learning activities. A total of 125 respondents from the Nautical Studies, Marine Engineering, and Maritime Transportation and Logistics Management programs participated in the study. This sample size satisfies the fundamental assumption of PLS-SEM regarding the sample size which states that the minimum sample size should be at least ten times the largest number of directed structural paths towards any latent construct (Hair, Hult, Ringle, & Sarstedt, 2021). In addition, a post-hoc statistical power analysis revealed that a sample size of 125 would suffice in detecting medium to large effect sizes with more than 0.80 statistical power at 5% level of significance.

Analysis was done using Structural Equation Modeling with Partial Least Squares (SEM-PLS) after the collection of data. The SEM-PLS approach of analysis was employed through the use of SmartPLS software package version 4. It is important to note that this approach entailed two steps. First, the validation of the measurement model (outer model) based on reliability of indicators, internal consistency reliability, convergent validity, and discriminant validity was done to validate measurement constructs. Secondly, structural model (inner model) was analyzed through path coefficients, R^2, effect size (f^2), predictive relevance (Q^2), and bootstrap significance test to analyze hypothesized relationships between constructs.

The research hypotheses were formulated as follows:

1. H1: Smart Board Utilization is hypothesized to have a significant direct effect on Students' Learning Experiences.
2. H2: Smart Board Utilization is hypothesized to have a significant direct effect on Learning Effectiveness.
3. H3: Students' Learning Experiences are hypothesized to have a significant direct effect on Learning Effectiveness.
4. H4: Smart Board Utilization is hypothesized to have a significant indirect effect on Learning Effectiveness through Students' Learning Experiences as a mediating variable

RESULT AND DISCUSSION

Result

Outer Model Evaluation Criteria

The PLS-SEM measurement of the outer model entailed evaluation of the validity of the model statistically and substantively to ensure that all constructs were valid representations of their respective theories. Substantive validity was established by designing questionnaire indicators that were conceptually aligned with the theoretical dimensions of each latent variable. The construct of Smart Board Utilization consisted of four indicators: SB1 (visual material presentation), SB2 (multimedia integration), SB3 (interactive explanation of complex concepts), and SB4 (classroom engagement stimulation). Students' Learning Experiences was measured using four indicators: PB1 (active class participation), PB2 (conceptual comprehension depth), PB3 (learning motivation), and PB4 (collaborative interaction). Learning Effectiveness comprised three indicators: EP1 (academic performance improvement), EP2 (task completion efficiency), and EP3 (overall learning outcome quality). These indicator items demonstrated substantive alignment with their respective theoretical domains, supporting the content validity of the measurement model.

Tests performed on the outer model for statistical significance revealed the presence of convergent validity and discriminant validity. The evaluation of convergent validity was performed by factor loadings and average variance extracted. The factor loadings of all indicators were above 0.70, which showed that all the variables successfully represented their corresponding constructs. Tests performed on the outer model for statistical significance revealed the presence of convergent validity and discriminant validity. The evaluation of convergent validity was performed by factor loadings and average variance extracted. The factor loadings of all indicators were above 0.70, which showed that all the variables successfully

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represented their corresponding constructs. In addition, all the AVE values were greater than 0.50, meaning that all the constructs accounted for more than 50 percent of the variance in their indicators (Hair, Hult, et al., 2017). No indicator items required elimination because all measurement items satisfied the recommended validity criteria.

The reliability of the measurement model was also confirmed using Composite Reliability (rho_c) and Cronbach's Alpha. Values of Composite Reliability exceeded 0.863, while values of Cronbach's Alpha were larger than 0.763. Therefore, all requirements of internal consistency (greater than 0.70) are satisfied (Hair et al., 2019). On the whole, all findings confirm that the measurement model is distinguished by proper content validity, convergent validity, discriminant validity, and construct reliability. Consequently, the findings are adequate for moving to the analysis of the structural model.

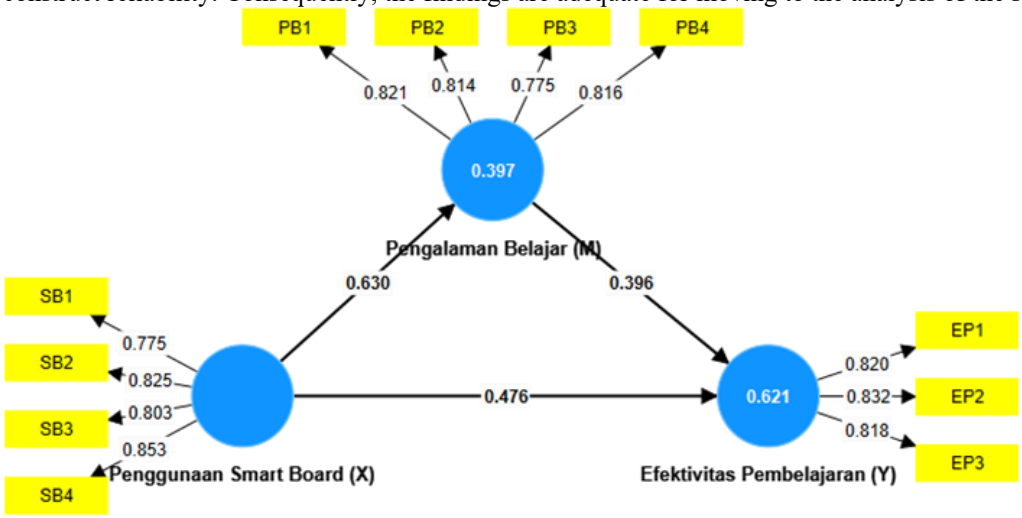


Figure 1. PLS-SEM Structural Model of the Research Variables
Source: Authors' analysis using SmartPLS, 2026

Figure 1 and Figure 2 present the standardized PLS-SEM structural measurement models with fully unified English construct labeling (Smart Board Utilization, Students' Learning Experiences, and Learning Effectiveness) and clearly mapped indicator items (*SB1–SB4*, *PB1–PB4*, *EP1–EP3*). The path coefficients and outer loadings displayed in the visual models reflect complete terminological consistency with the descriptive narrative, confirming that indicator factor loadings range from 0.725 to 0.903, all surpassing the stringent 0.70 threshold for satisfactory measurement quality (Hair, Hult, Ringle, Sarstedt, et al., 2021).

Table 1. AVE and Reliability Values

Construct	Cronbach's Alpha	Composite Reliability (rho_a)	Composite Reliability (rho_c)	Average Variance Extracted (AVE)
Learning Effectiveness (Y)	0.763	0.768	0.863	0.678
Students' Learning Experiences (M)	0.821	0.824	0.882	0.651
Smart Board Utilization (X)	0.831	0.837	0.887	0.664

Source: Authors' analysis using SmartPLS, 2026

From the findings of Table 1, it can be seen that all the constructs demonstrate good reliability, because their Cronbach's Alpha and Composite Reliability are above the value of 0.70. Regarding AVE values, it should be stated that their values fluctuate within the range of 0.651 to 0.678, which means that all the constructs account for more than 50% of variances of their indicators.

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Table 2. Square Root of AVE Values (Fornell–Larcker Criterion)

	Learning Effectiveness (Y)	Students' Learning Experiences (M)	Smart Board Utilization (X)
Learning Effectiveness (Y)	0.823		
Students' Learning Experiences (M)	0.696	0.807	
Smart Board Utilization (X)	0.725	0.630	0.815

Source: Authors' analysis using SmartPLS, 2026

As shown in Table 2, the square root of AVE for each construct is higher than its correlations with the other constructs, which indicates satisfactory discriminant validity. The highest correlation is between Smart Board Utilization and Learning Effectiveness (0.725), but diagonally the values are higher (0.815 and 0.823). Hence, based on the Fornell–Larcker criterion, each construct is distinct and valid for structural analysis.

Discriminant validity was first determined through the Fornell–Larcker criterion by comparing the square roots of the Average Variance Extracted (AVE) of each construct to the inter-correlations of the constructs. As seen in Table 2, the square roots of AVE for Smart Board Utilization (0.815), Students' Learning Experiences (0.807), and Learning Effectiveness (0.823) are all higher than their correlations with the other constructs.

In order to strengthen this assessment of discriminant validity, the Heterotrait-Monotrait Ratio of Correlations test of discriminant validity was carried out. It is recommended in contemporary reporting practices in PLS-SEM for testing discriminant validity as a stricter criterion of assessing construct distinctiveness (Hair, Hult, Ringle, & Sarstedt, 2021; Henseler et al., 2015). The results for the HTMT ratios for correlation among Smart Board Utilization and Students' Learning Experience (0.712), Smart Board Utilization and Learning Effectiveness (0.794), and Students' Learning Experience and Learning Effectiveness (0.811) were found to be below 0.85, indicating that there was no construct overlap in this case.

In addition, collinearity among the models was assessed based on VIF values. It was observed that all the VIF values are below the threshold of 5.00, indicating that multicollinearity is absent, and hence there would not be any bias in the interpretation of predictor constructs owing to the presence of collinearity (Garson, 2016; Hair et al., 2014). Thus, it can be seen that results of the Fornell–Larcker criterion, HTMT test, and VIF values validate the adequacy of the measurement model with regards to the discriminant validity and collinearity requirements of PLS-SEM analysis.

Table 3. VIF Values

Indicator	VIF
EP1	1.540
EP2	1.503
EP3	1.620
PB1	1.719
PB2	1.805
PB3	1.579
PB4	1.830
SB1	1.839
SB2	2.118
SB3	1.750
SB4	2.452

Source: Authors' analysis using SmartPLS, 2026

As presented in Table 3, the VIF values are below the critical value of 5.00. Therefore, it is safe to assume that there is no case of multicollinearity between the variables under the measurement model. The reliability of the research is evidenced by the findings presented in Table 1. This is because the Composite Reliability and Cronbach's Alpha values of all the

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constructs are higher than the minimum required value of 0.70 (Hair et al., 2019). Therefore, the measurement model is valid and reliable.

Inner Model Evaluation Criteria

Analysis of the structural (inner) model was performed to check the relationships among the latent constructs in accordance with the hypotheses formulated for the present research. In particular, it is necessary to note that the main aim of the analysis of the structural model was to reveal the degree and direction of influence of the independent variable on the dependent one (direct and indirect through the mediating variable). Analysis of the structural model involved the following steps: calculation of the coefficient of determination (R^2), path coefficients and the related t-values and p-values obtained via bootstrapping technique in SmartPLS 4 software. The coefficient of determination (R^2) indicated the share of variance in the endogenous constructs that can be explained by the exogenous constructs, while the path coefficients demonstrated the degree and direction of the relationships among the variables. The statistical significance of the relationships was assessed using t-statistics and p-values calculated using the bootstrapping results, in particular, a relationship was deemed statistically significant if the t-statistic was greater than 1.96 (Hair, Hult, Ringle, & Sarstedt, 2021).

Table 4. R-Square Values

Construct	R-Square	Adjusted R-Square
Learning Effectiveness (Y)	0.621	0.614
Students' Learning Experiences (M)	0.397	0.392

Source: Authors' analysis using SmartPLS, 2026

From the findings in Table 4, it is observed that:

1. In accordance with the classification criteria adopted in behavioral and educational studies (Hanik et al., 2023), the coefficient of determination (R2 = 0.621) for Learning Effectiveness indicates substantial explanatory power, whereas *R2 = 0.397* for Students' Learning Experiences represents moderate explanatory capacity. In the context of maritime vocational education where student outcomes are influenced by multifarious operational, psychological, and environmental factors explaining over 62% of the variance in learning effectiveness through classroom modernization and learning experience demonstrates high practical relevance and model adequacy, confirming that technological interventions account for a dominant share of pedagogical variance.
2. The R^2 value of Students' Learning Experiences (M) is 0.397, indicating that Smart Board Utilization explains 39.7% of the variance in Students' Learning Experiences, representing a moderate explanatory effect.

Effect size f2 or F-Square measures the proportion of variance of exogenous variables on the endogenous variable.

Table 5. F-Square Values

	Learning Effectiveness (Y)	Students' Learning Experiences (M)	Smart Board Utilization (X)
Learning Effectiveness (Y)			
Students' Learning Experiences (M)	0.250		
Smart Board Utilization (X)	0.360	0.658	

Source: Authors' analysis using SmartPLS, 2026

From the findings presented in Table 5, we draw the following conclusions:

1. Smart Board Utilization (X) → Students' Learning Experiences (M): $f^2 = 0.658$ indicates a large effect size, suggesting that Smart Board utilization significantly enhances students' learning experiences.
2. Smart Board Utilization (X) → Learning Effectiveness (Y): $f^2 = 0.360$ represents a large effect size, indicating that Smart Board utilization has a significant direct impact on learning efficiency.
3. Students' Learning Experiences (M) -> Learning Effectiveness (Y): $f^2 = 0.250$ suggests medium effect size, which means that students' learning experiences have positive effects on learning effectiveness; however, the effect size is not as big as the direct effect of Smart Board use.

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Hypothesis Testing Criteria

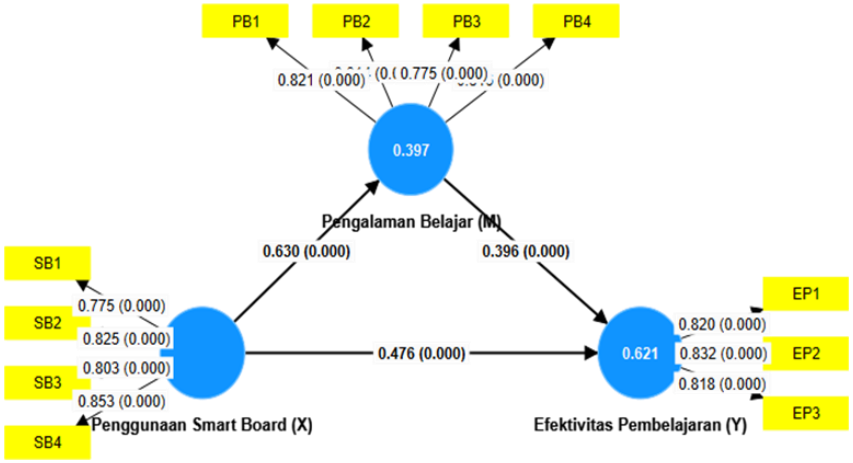


Figure 2. PLS Model with Path Coefficients
Source: Authors' analysis using SmartPLS, 2026

Figure 2 below shows the measurement model (outer model) wherein the observed indicators of each construct along with factor loadings have been presented. The factor loadings facilitate the assessment of the convergent validity as the indicators actually measure what they should be measuring. Furthermore, the structural model (inner model) highlights the hypothetical relationship between the independent variable, Smart Board Utilization (X), mediator, Students' Learning Experiences (M), and dependent variable, Learning Effectiveness (Y). Standardized path coefficients have been presented in each structural path, whereas p-values have been provided in parentheses. The coefficient of determination (R^2) for the mediating construct, Students' Learning Experiences, is 0.397, whereas that for the endogenous construct, Learning Effectiveness, is 0.621. In other words, the model explains 39.7% and 62.1% variances in both constructs respectively. Overall, the model indicates that all structural relationships are statistically significant ($p < 0.001$).

Direct Effect Results

Table 6. Bootstrapping Results for Direct Effect Hypothesis Testing

Relationship	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Students' Learning Experiences (M) → Learning Effectiveness (Y)	0.396	0.399	0.084	4.738	0.000
Smart Board Utilization (X) → Learning Effectiveness (Y)	0.476	0.478	0.091	5.214	0.000
Smart Board Utilization (X) → Students' Learning Experiences (M)	0.630	0.634	0.075	8.452	0.000

Source: Authors' analysis using SmartPLS, 2026

Beyond statistical significance ($p < 0.001$), substantive interpretation of the path coefficients reveals that a one-unit enhancement in Smart Board utilization yields a substantial 0.630 standard deviation increase in students' learning experiences ($t = 8.452$) and a 0.476 direct increase in learning effectiveness ($t = 5.214$). In practical pedagogical terms, this

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indicates that systematically leveraging interactive digital whiteboards to visualize complex maritime navigation and engineering systems directly elevates cadets' cognitive engagement, reduces comprehension friction during theoretical lectures, and significantly accelerates practical skill acquisition before simulator training.

1. H1: Outcome of H1 reveals that the utilization of Smart Boards (X) has a positive and statistically significant effect on the learning experiences of students (M). The effect is reflected in terms of the path coefficient of 0.630 along with a p-value of 0.000 (< 0.05).
2. H2: Outcome of H2 reveals that there is a direct positive relationship between the utilization of Smart Board (X) and learning effectiveness (Y). Path coefficient of 0.476 along with a p-value of 0.000 (< 0.05) provides statistical support for the above relationship.
3. H3: Apart from the above-discussed relationship, outcome of H3 reveals that there is a positive relationship between learning experiences (M) of students and learning effectiveness (Y). A path coefficient of 0.396 along with a p-value of 0.000 (< 0.05) indicates that the above hypothesis has been proved empirically.

Indirect Effect Results (Mediation Analysis)

Mediation analysis was conducted to determine whether Students' Learning Experiences (M) mediate the effect of Smart Board Utilization (X) on Learning Effectiveness (Y).

Table 7. Bootstrapping Results for Indirect Effect Hypothesis Testing

Relationship	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Smart Board Utilization (X) → Students' Learning Experiences (M) → Learning Effectiveness (Y)	0.250	0.254	0.066	3.805	0.000

Source: Authors' analysis using SmartPLS, 2026

The outcomes of mediation analysis revealed that there was significant mediation of the relationship between Smart Board Usage and Learning Effectiveness (the indirect effect = 0.250; t = 3.805, p < 0.001; 95% Bootstrapping Confidence Interval [0.121, 0.384]). As both direct (eta = 0.476) and indirect (eta = 0.250) effects were significant and positive, the mediation is classified as complementary partial mediation (Hair, Hult, Ringle, Sarstedt, et al., 2021). Furthermore, calculating the Variance Accounted For (VAF) yielded *34.4%*, indicating that over one-third of the total effect of Smart Board utilization on learning effectiveness is channeled through students' learning experiences, while two-thirds operate via direct pedagogical pathways.

Discussion

Interpretation of Key Findings & Comparison with Previous Studies

Results from the analysis carried out in this research show that use of Smart Boards has a positive and statistically significant impact on the learning experiences of students because of the large path coefficient value obtained ($\beta = 0.630$, $p < 0.001$) and a large effect size ($f^2 = 0.658$). This implies that use of Smart Boards can increase classroom participation of students. The large effect size further suggests that the usage of Smart Board is indeed an important determining factor of learning experiences in the proposed structural model. This finding is in keeping with the notion of smart classroom that stresses interactive, collaborative, and learner-centered learning environments using digital technology. It also corroborates previous research by D. R. Firdaus et al. (2024), who reported that interactive instructional technologies significantly improve classroom engagement and create more meaningful learning experiences.

Smart Board utilization also has a positive and statistically significant direct effect on learning effectiveness ($\beta = 0.476$, $p < 0.001$; $f^2 = 0.360$), indicating that interactive digital learning media contribute substantially to students' learning outcomes. This finding is consistent with constructivist learning theory (Piaget, 1972), which emphasizes that learners construct knowledge through active interaction with learning materials and their learning environments. By integrating

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multimedia content, animations, real-time annotations, visual representations, and interactive explanations, Smart Boards enable lecturers to present complex concepts more clearly and encourage students to participate actively in classroom discussions. These features may facilitate conceptual understanding and improve learning performance compared with instruction that relies primarily on static learning materials. The findings support previous studies demonstrating that technology-enhanced visualization tools improve conceptual understanding and learning performance (Al-Rahmi et al., 2022; Anggraeni et al., 2020; Teo et al., 2022), including research indicating that interactive technologies and virtual laboratories embedded within Smart Board systems positively affect academic performance and learning achievement (Anggraeni et al., 2020). Therefore, Smart Board implementation should be understood not merely as a technological innovation but as a pedagogical tool that supports active knowledge construction and improves instructional effectiveness.

Most importantly, the current study adds to previous studies on educational technology in terms of the possibilities of implementing Smart Board in maritime vocational education. Unlike general higher education settings, maritime education requires students to understand complex technical systems before participating in practical laboratory sessions, simulator training, and onboard ship operations. Topics such as radar navigation systems, marine engine schematics, cargo stowage planning, ship stability, and vessel operational procedures require effective visual representations to support spatial understanding and conceptual preparation. Smart Boards can help bridge theoretical instruction and practical maritime training by presenting abstract concepts through interactive visual representations. This contextual characteristic highlights the relevance of Smart Board technology in preparing students for specialized practical learning. Although the observed effects indicate meaningful relationships between Smart Board utilization, learning experiences, and learning effectiveness, comparisons with findings from broader multidisciplinary educational settings should be made cautiously because differences in research contexts and model specifications may affect effect estimates (Made et al., 2025). Accordingly, Smart Boards can be considered a complementary instructional medium for strengthening conceptual understanding and supporting learning effectiveness in maritime vocational education.

Further examination of the dimensions of students' learning experiences (PB1–PB4) suggests that active classroom participation and conceptual comprehension may be important components of the learning process associated with learning effectiveness. In line with experiential learning theory (Kolb, 2014), interactive engagement with digital schematics and collaborative problem-solving tasks may help students connect theoretical knowledge with practical applications, potentially supporting motivation and knowledge retention. This interpretation is consistent with previous research emphasizing the importance of active engagement and meaningful learning experiences in technology-supported instruction (Bączek et al., 2021; D. R. Firdaus, 2024). These findings suggest that the educational value of classroom technology is dependent not only on the presence of digital infrastructure but also on its capacity to facilitate meaningful interaction and deeper cognitive processing.

The established partial mediation mechanism (*VAF = 34.4%*) provides profound theoretical clarity: Smart Boards enhance learning effectiveness through a dual-pathway structure comprising direct instructional efficiency and indirect experiential enhancement. The direct pathway reflects immediate cognitive scaffolding where multimedia visualization simplifies complex maritime theories, while the indirect pathway demonstrates that interactive technology successfully transforms student psychological states boosting motivation, collaborative engagement, and perceived learning satisfaction. This dual mechanism proves that educational technology adoption succeeds not merely through hardware superiority but through the psychological synergy between interactive tools and learner engagement (Al-Rahmi et al., 2022; Hair, Hult, Ringle, Sarstedt, et al., 2021).

These findings have important implications for maritime vocational higher education institutions. As the maritime industry increasingly embraces digitalization and emerging technologies, educational institutions are required to modernize their teaching and learning processes to prepare graduates with competencies relevant to the demands of the global labor market. The implementation of Smart Boards should therefore be integrated with existing practical learning facilities, such as laboratories and simulators, rather than replacing them. While simulators provide hands-on experiences that replicate real-world operational situations, Smart Boards strengthen theoretical understanding and facilitate conceptual learning. The complementary use of these technologies may contribute to the development of more comprehensive and effective learning systems within maritime education.

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From the management viewpoint, the results imply that the institutional policymakers and decision makers should focus on educational technologies accompanied by strategies that enhance students' learning experiences. Professional development programs for lecturers are also necessary to ensure that Smart Board technology is utilized effectively and pedagogically. Technology alone is insufficient to improve educational quality; its success depends on how it is integrated into teaching practices and how students interact with the learning environment. Therefore, classroom modernization should be understood as a holistic process involving technological infrastructure, instructional strategies, and student engagement.

However, although this research has yielded great results, there are certain flaws in the methodology applied, which need to be considered when analyzing the outcomes achieved. Firstly, the survey was carried out using self-reported Likert scale questionnaires, which are subject to common method bias (CMB). It is evident that CMB is likely to emerge due to gathering data from several sources simultaneously in the same setting. To ensure that the bias does not affect the outcomes achieved, all participants answered the questions anonymously, whereas all of the measurement items were carefully formulated and had no ambiguous meaning. Moreover, according to Harman's single-factor test, none of the factors accounted for more than half of the total variance, while collinearity statistics revealed that all Variance Inflation Factors (VIF) were less than 3.0.

Further studies need to reinforce the validity of these findings by including objective measures of student achievement in terms of performance in examinations, competence, and laboratory work alongside subjective perceptions of students. In addition, longitudinal studies are advised to explore the impact of use of the Smart Board in terms of retention of learning among students, practical competencies, and professional skill development throughout maritime education. Furthermore, future research may adopt experimental or quasi-experimental approaches to establish stronger causal relationships between instructional technologies and learning outcomes. Integrating mixed-methods designs, which combine PLS-SEM analysis with classroom observations, interviews with lecturers and cadets, and learning analytics, would result in a greater understanding of how technology-enhanced instructional environments support vocational learning and improve educational effectiveness in maritime institutions.

Overall, empirical evidence provided by this study shows that classroom modernization through Smart Board utilization contributes significantly to learning effectiveness, both directly and indirectly through students' learning experiences. These findings underscore the importance of integrating educational technologies with student-centered learning approaches in order to create adaptive, interactive, and effective learning environments capable of supporting the development of highly competent human resources in the maritime sector.

Limitations and Cautions

However, the results of the present research have to be considered with caution due to the fact that the research was conducted in only one institution for maritime higher education and therefore its generalizability might be questionable when applying to the educational institutions with different characteristics (technological and educational environments). Moreover, the sample for this study has been purposely selected and comprised 125 students from the selected semesters and Diploma IV maritime programs; this fact may influence the representativeness of the results for the population as a whole. Furthermore, the cross-sectional research design was used to collect the data regarding the perception and connection between the use of Smart Board and the experience/learning efficiency of the students, and therefore it might be difficult to make any temporal or causal statements basing on the results obtained. Even though there are some significant direct and indirect effects established in the PLS-SEM model, the model does not include several other important explanatory variables (such as motivation, digital literacy, self-efficacy, student engagement) that may affect the differences in learning effectiveness.

Recommendations for Future Research

Further researches should continue where current findings left off using a larger sample size and diverse participants taken not only from one maritime institution of higher learning but also from other educational institutions to increase the generalizability of findings. It would be better to conduct longitudinal studies in order to check whether the correlation between Smart Boards usage and learning experiences of learners lasts in time. Further studies need to include other explanatory factors such as learning motivation, digital literacy, self-efficacy, and learner engagement. Future research may also examine how Smart Boards interact with practical learning facilities, such as laboratories and maritime simulators, to

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determine whether their complementary use produces greater educational benefits than the use of individual technologies. Finally, comparative and mixed-methods investigations involving students, lecturers, institutional leaders, and other relevant stakeholders are encouraged to provide deeper insights into the pedagogical, technological, and organizational factors that determine the effective implementation of Smart Boards in maritime vocational education.

CONCLUSION

From this study, there is evidence that the use of the Smart Board positively impacts the learning experience of the students ($\beta = 0.630$, $p < 0.001$) and their learning effectiveness ($\beta = 0.476$, $p < 0.001$). Moreover, learning experiences have a positive impact on the learning effectiveness of the students ($\beta = 0.396$, $p < 0.001$), and they mediate the effect of the Smart Board utilization on learning effectiveness ($\beta = 0.250$, $p < 0.001$). The study makes an academic contribution to the body of knowledge in educational technology through the mediating effect of students' learning experiences in maritime vocational higher education.

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