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Rethinking ICT Integration in Indonesian Schools: The Role of Digital Self-Learning Beyond Institutional Support

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Abstract

Purpose of the Study: This study examines the relationships among Digital Self-Learning (DSL), Institutional Support (IS), Professional Development (PD), and Technology Integration (TI) among Indonesian teachers. Specifically, the study investigates how teachers' autonomous digital learning behavior contributes to classroom-level ICT integration beyond formal institutional and training mechanisms.

Methodology: A quantitative cross-sectional survey was conducted involving 221 Indonesian in-service teachers. The study applied Partial Least Squares Structural Equation Modeling (PLS-SEM) to analyze the data, examine relations among the proposed constructs, and explore the mechanisms underlying technology integration.

Main Findings: Digital Self-Learning is the strongest predictor of both Professional Development and Technology Integration. Institutional Support significantly influences Digital Self-Learning but does not directly affect Technology Integration, suggesting that institutional conditions primarily contribute through enabling teachers' self-directed learning behavior. Professional Development further strengthens Technology Integration, whereas demographic variables such as age, gender, and educational level exert little influence. Although the proposed model confirmed substantial explanatory power, its out-of-sample projecting performance was limited. Therefore, the findings should be interpreted primarily from an explanatory rather than a predictive perspective.

Novelty/Originality of this Study: The novelty of this study lies in its reconceptualization of ICT integration as a behaviorally driven process in which Digital Self-Learning functions as the central mechanism linking institutional conditions, professional growth, and classroom technology integration. The findings contribute to the growing discourse on teacher digital capability and offer practical insights for developing more adaptive and sustainable ICT integration strategies in educational settings.

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INTRODUCTION

The integration of information and communication technology (ICT) in education has attracted growing global attention as education systems seek to strengthen digital skills, improve access to learning, enhance engagement, and improve instructional effectiveness (Kumsar & Priyanka, 2023; Consoli et al., 2025). Beyond enhancing instructional delivery, ICT enables more flexible, accessible, and student-centered learning environments, particularly through digital platforms, online resources, and interactive media (Anastasopoulou et al., 2024; Prajapati, 2025; Awidi & Paynter, 2024). As a result, effective technology integration is gradually known as a primary determinant of learning quality and student engagement (Balalle, 2024; Zafeer et al., 2025; Consoli et al., 2025).

In the Indonesian context, the implementation of the Merdeka Curriculum explicitly emphasizes integrating digital technologies to foster innovation, flexibility, and learner autonomy (Yahya et al., 2025; Fahrudin et al., 2022). Despite strong policy direction, the adoption of ICT in classrooms

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remains uneven due to persistent challenges, including infrastructure disparities, limited access to digital resources, and variations in teachers' digital competence (Rustanto & Supriyadi, 2025; Salsabila & Zuhairi, 2025; Suwarni & Natsir, 2024). These challenges highlight a critical issue: the availability of technology alone does not guarantee meaningful integration of technology in teaching practice.

Prior research has traditionally positioned Professional Development (PD) and Institutional Support (IS) as primary drivers of ICT integration. Structured training programs, institutional policies, and access to technological infrastructure are widely assumed to enhance teachers' digital competence and facilitate classroom implementation (Amemasor et al., 2025; Theodorio, 2024). Nevertheless, emerging evidence proposes that these formal and institutional mechanisms may not fully capture how teachers actually develop and apply digital competencies in practice, particularly in resource-constrained environments (Graham et al., 2023; Haryanto et al., 2026).

However, growing evidence suggests that conventional ICT professional development programs often produce limited and unsustainable impacts on classroom technology integration (Avci et al., 2020). Many training initiatives continue to rely on centralized, top-down approaches that emphasize one-time workshops, standardized content, and compliance with institutional policies rather than teachers' ongoing learning needs. Such approaches frequently fail to support continuous competence development, contextual adaptation, and sustained changes in instructional practice (Amemasor et al., 2025; Khoiro et al., 2025; Lidolf & Pasco, 2020). Consequently, educators frequently struggle to transfer newly acquired digital competence into authentic classroom settings after formal training ends (Mouza et al., 2022).

Against this backdrop, recent studies have increasingly highlighted the role of Digital Self-Learning (DSL) as an alternative mechanism for teachers to continuously acquire and update digital competencies beyond formal institutional training. Digital Self-Learning refers to teachers' self-directed efforts to acquire digital skills through informal, autonomous, and technology-mediated learning activities (Caena & Redecker, 2019; Mohiyeddini, 2024; Chiu et al., 2024). Unlike conventional professional development, Digital Self-Learning is self-initiated, flexible, and embedded in teachers' everyday instructional practice. Through online communities, digital platforms, tutorials, peer collaboration, and continuous experimentation with digital tools, teachers can independently adapt to rapidly evolving technologies and pedagogical innovations without relying solely on formal training structures (Linde et al., 2023; Sathya & Alamelu, 2026; Beach et al., 2022). This perspective aligns with the DigCompEdu framework, which emphasizes self-directed engagement as a critical component of teachers' digital competence (Christine, 2017) Consequently, Digital Self-Learning has increasingly been recognized as a promising pathway for the sustainable development of digital competence.

Despite this increasing recognition, a number of important research gaps persist in the literature. First, existing studies tend to treat Professional Development as the dominant pathway to technology integration, while the potential of Digital Self-Learning as a primary driver remains underexplored. This raises an important theoretical issue regarding the primary mechanism by which teachers develop sustainable digital competence: whether technology integration is driven predominantly by formal professional development or by teachers' continuous, autonomous learning (Gui et al., 2026; Fransson & Norman, 2021).

Second, the role of Institutional Support is often conceptualized as a direct determinant of ICT adoption. However, empirical findings are inconsistent, with some studies suggesting that institutional factors may influence technology integration only indirectly through behavioral mechanisms such as motivation, self-efficacy, or self-directed learning (Graham et al., 2023). inconsistency indicates a need to clarify the mechanism through which institutional conditions translate into actual classroom practices.

Third, demographic variables such as age, gender, and education level are frequently involved as predictors of digital competence, yet their effects remain inconclusive and often marginal compared to behavioral and contextual factors (Mulyanti et al., 2024; Suzer & Koc, 2024). This suggests that technology integration may be determined less by who teachers are and more by how they learn and are supported.

Addressing these gaps is mainly important in developing settings such as Indonesia, where formal training opportunities may be limited, and institutional conditions vary widely. In such settings, understanding the interplay between self-directed learning, institutional support, and professional development is crucial for designing effective ICT integration strategies. Most ICT integration studies continue to assume that formal professional development constitutes the primary mechanism for improving teachers' digital competence. In contrast, this study argues that Digital Self-Learning represents a complementary and potentially more influential behavioral pathway through which teachers continuously develop and apply digital competencies beyond the limitations of conventional institutional training.

Therefore, this study aims to develop a comprehensive model and conduct an empirical test examining the relationships among Digital Self-Learning, Institutional Support, Professional Development, demographic factors, and Technology Integration among Indonesian teachers. Using Partial Least Squares Structural Equation Modeling (PLS-SEM), this study explores how these factors interact to shape teachers' ICT integration practices. By integrating individual learning behavior with institutional conditions, this study advances the wider scholarly discussion on ICT-enhanced education and provides practical insights for designing more adaptive, scalable, and sustainable strategies for technology integration in schools.

METHOD

1. Research Design

This research employs a quantitative method using a cross-sectional survey and utilizes PLS-SEM. PLS-SEM was preferred due to its ability to accommodate a mix of formative and reflective constructs, multiple predictors, and mediating models, and is best suited for predictive research in an emerging educational setting (Sarstedt & Liu, 2024; Hair et al., 2019).

The study employed PLS-SEM rather than covariance-based SEM (CB-SEM) for several methodological reasons. First, the sample size was intermediate (N = 221), which is adequate for PLS-SEM given its less stringent distributional preferences relative to CB-SEM. Second, the model combines reflective and formative constructs, which PLS-SEM is better suited to accommodate. Third, its research purpose is prominently predicated on the explanatory power of Digital Self-Learning, Institutional Support, and Professional Development towards Technology Integration. This aligns with the capabilities of PLS-SEM, whereas CB-SEM is more appropriate for confirmatory testing of established theoretical models (Sarstedt & Liu, 2024).

Therefore, the research investigated how demographics (age, gender, and education), Digital Self-Learning, and Institutional Support relate to teachesrs' Professional Development in Indonesia.

a. Sample and Data Collection

Teachers who participated in this study were in-service teachers from primary, junior high, and senior high schools in Indonesia who had experience using digital technology in their teaching practices. To ensure representation across different educational levels and geographical settings, stratified sampling was employed (Ahmed, 2024).

The online survey was conducted between March and May 2025 through institutional mailing lists and professional teacher communities. The questionnaire was piloted with 30 teachers, and minor adjustments were made to enhance item clarity and contextual suitability before the main survey was conducted. Following data screening, 221 valid responses were included in the final analysis.

Table 1 summarizes the respondents' demographic characteristics. The sample comprised teachers from primary schools (16.7%), junior high schools (32.6%), and senior high schools (50.7%). Respondents represented diverse geographical settings, including the national capital (9.5%), provincial capitals (12.7%), regency or city areas (38.5%), district towns (26.2%), and rural areas (13.1%), providing a broad contextual representation of Indonesian schools. The majority of teachers had completed a Diploma or Bachelor's degree (89.6%), whereas 8.6% had obtained a Master's degree and 1.8% had completed a Doctoral degree. Female teachers accounted for 62.9% of the sample, whereas male teachers represented 37.1%. The respondents also reflected a wide age

distribution, with Generation Y (28–43 years) comprising the largest proportion (38.0%), followed by Generation X (31.2%), Generation Z (27.6%), and Baby Boomers (3.2%). This demographic diversity enhances the study's transparency and supports the applicability of the findings across diverse educational contexts in Indonesia.

b. Instrument Development

The survey instrument was adapted from validated measures in prior studies and aligned with the European Framework for the Digital Competence of Educators (DigCompEdu) (Christine, 2017). Institutional Support was operationalized as a formative construct comprising three indicators that measured access to digital infrastructure, training opportunities, and leadership support (Aad & Ginzarly, 2024). Digital Self-Learning was specified as a reflective construct and conceptualized based on DigCompEdu's *Facilitating Learners' Digital Competence* dimension, which emphasizes teachers' autonomous and self-directed digital learning behaviors. Professional Development was also modeled as a reflective construct, encompassing teachers' engagement in training activities, peer support, and professional learning networks. This construct corresponds to the *Professional Engagement* area of DigCompEdu, highlighting continuous reflective practice and collaborative professional growth (Horváth et al., 2025). Technology Integration was measured as a reflective construct using four items that assessed the extent to which digital technologies were integrated into teaching, learning, and assessment, consistent with DigCompEdu Areas 2 and 3 (Mulyanti et al., 2024). Demographic data, comprising age, gender, and highest educational attainment, were also gathered and treated as control variables.

Table 1. Demographic Profile of Respondents (N = 221)

No	Characteristic	Category	n	%
1	School category	Primary School (SD)	37	16.7
		Junior High School (SMP)	72	32.6
		Senior High School (SMA/SMK)	112	50.7
2	School Location	National Capital	21	9.5
		Provincial Capital	28	12.7
		Regency/City	85	38.5
		District Town	58	26.2
		Rural Area	29	13.1
3	Teacher education level	Diploma/Bachelor's Degree	198	89.6
		Master's Degree	19	8.6
		Doctoral Degree	4	1.8
4	Gender	Male	82	37.1
		Female	139	62.9
5	Age Group	18–27 years (Generation Z)	61	27.6
		28–43 years (Generation Y)	84	38.0
		44–59 years (Generation X)	69	31.2
		60–65 years (Baby Boomers)	7	3.2
	Total Respondents		**221**	**100.0**

All indicators of the constructs were assessed using a Likert scale. The scale ranged from 1 (strongly disagree) to 5 (strongly agree). The instrument was reviewed by three professionals in educational technology and psychometrics and subsequently refined through pilot testing to strengthen content validity and ensure contextual suitability. The final survey instrument is reported in Table 2.

Table 2. Constructs, Example Items, and Framework Sources

Construct	Example Items (adapted)	Framework/Source
Demographics	Gender, Year of birth, Highest educational qualification	Standard demographic variables
Institutional Support (Formative)	IS1: My school provides reliable internet access. IS2: My school offers regular digital training opportunities.	(Aad & Ginzarly, 2024)

Construct	Example Items (adapted)	Framework/Source
	IS3: School leaders encourage teachers to adopt digital technologies.	
Digital Self-Learning (Reflective)	DS1: I use tutorials and online resources to enhance my teaching. DS2: I reflect on my teaching practices using digital tools. DS3: I actively participate in online professional learning opportunities. DS4: I use digital technologies to record and reflect on my teaching in order to improve my professional knowledge and digital skills. DS5: I actively manage my motivation and learning focus to continuously develop my digital competencies.	DigCompEdu Area 6 (Christine, 2017)
Professional Development (Reflective)	PD1: I enroll in and complete online training courses. PD2: I participate in digital professional certifications. PD3: I assist colleagues in adopting new digital tools.	DigCompEdu Area 5 (Christine, 2017)
Technology Integration (Reflective)	TI1: I use digital tools (e.g., LMS, multimedia) to create engaging learning. TI2: I design collaborative digital activities. TI3: I provide digital feedback to students. TI4: I integrate innovative digital methods (e.g., webinars, social media).	DigCompEdu Areas 2 & 3 (Christine, 2017; Mulyanti et al., 2024)

c. Data Analysis

The data were analyzed using the two-step method of (Hair et al., 2019) in SmartPLS version 4.0.9.2. In the first step, the study evaluates construct validity and reliability. For reflective constructs, internal consistency was assessed using Cronbach's Alpha and Composite Reliability (CR), and convergent validity was assessed using the Average Variance Extracted (AVE). Then, the Fornell–Larcker criterion and the Heterotrait–Monotrait (HTMT) ratio are used to evaluate discriminant validity.

For the formative construct, Institutional Support, outer weights, their statistical significance, and multicollinearity were measured using bootstrapping and the Variance Inflation Factor (VIF). When outer weights were not statistically significant, outer loadings were subsequently examined as complementary evidence to assess the absolute contribution of formative indicators, taking into account their theoretical relevance, in line with (Hair et al., 2019).

In the next step, the study tests the model's hypothesized relationships. Following (Hair et al., 2019) guidance, the study examined path coefficients, R^2, and effect sizes (f^2) to evaluate the relationships among constructs and used PLSpredict to examine predictive relevance. The significance of the hypothesized paths was tested using bootstrapping with 5,000 resamples at a 95% confidence interval. This approach enabled the evaluation of both formative and reflective constructs within the proposed model.

2. Research Model

The research model proposes relationships among demographic variables (age, gender, and education), Digital Self-Learning, Institutional Support, Professional Development, and Technology Integration. In the proposed framework, Institutional Support is specified as an exogenous formative construct, while Digital Self-Learning, Professional Development, and Technology Integration are modeled as reflective constructs. Institutional Support was operationalized as a first-order formative construct comprising three indicators representing infrastructure support, digital training opportunities, and leadership encouragement. Digital Self-Learning functions as both an endogenous construct, influenced by Institutional Support and demographic variables, and as a mediator linking

Institutional Support to Professional Development and Technology Integration. Professional Development serves as an additional mediator influencing Technology Integration, whereas demographic variables are included as control variables.

The model was tested using PLS-SEM, as it allows both formative and reflective constructs, derived from different theoretical perspectives, to be incorporated into a single model. In addition, PLS-SEM is appropriate for theory extension in emerging research contexts and performs well when models include multiple independent variables and indirect effects (Sarstedt & Liu, 2024; Hair et al., 2019). Figure 1 illustrates the proposed conceptual model, encompassing both direct and indirect relationships among the constructs examined in this study. Specifically, the model conceptualizes the relationships among demographic characteristics, Institutional Support, Digital Self-Learning, Professional Development, and Technology Integration. Digital Self-Learning is proposed to mediate the relationship between Institutional Support and both Professional Development and Technology Integration, while Professional Development is expected to further enhance Technology Integration. Demographic variables (age, gender, and educational level) are included as control variables that influence Digital Self-Learning.

3. Conceptual Framework and Hypothesis Development

This study is grounded in the broader literature on ICT integration, teacher digital competence, and self-directed learning. Prior research has predominantly positioned Professional Development (PD) and Institutional Support (IS) as the primary drivers of technology integration in educational settings. Structured training programs, leadership support, and access to digital infrastructure are widely assumed to enhance teachers' ability to adopt and implement digital technologies in classroom practice (Amemasor et al., 2025; Wiyono et al., 2024).

However, this dominant perspective has been increasingly challenged by emerging evidence suggesting that formal and institutional mechanisms alone may not sufficiently explain how teachers develop and enact digital competence in practice. In particular, recent studies highlight the role of Digital Self-Learning (DSL) as a foundational behavioral mechanism through which teachers continuously acquire, adapt, and apply digital skills in response to evolving technological demands (Linde et al., 2023). Unlike formal training, Digital Self-Learning is autonomous, ongoing, and context-responsive, enabling teachers to bridge gaps left by limited institutional provision. Unlike general digital competence, which primarily reflects teachers' existing technological capabilities, Digital Self-Learning emphasizes the continuous, autonomous process by which teachers independently acquire and update digital pedagogical competencies outside formal institutional structures. In this regard, Digital Self-Learning is conceptualized not merely as a competence outcome, but as an ongoing adaptive learning behavior that supports sustained ICT integration.

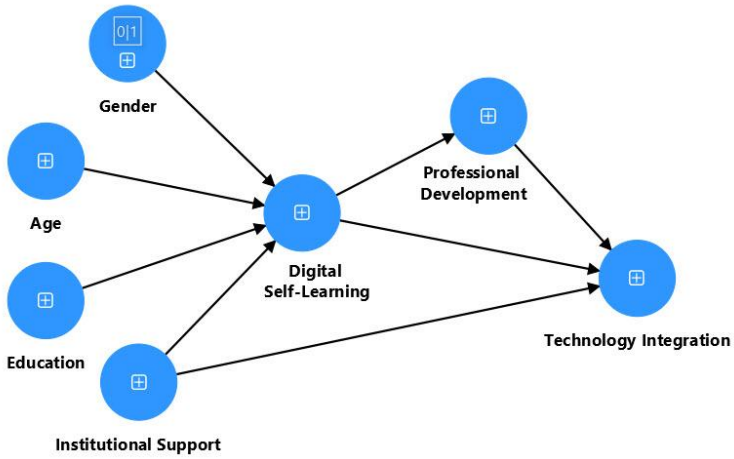

Figure 1. Research Model

From a theoretical perspective, this study aligns with the DigCompEdu framework, which emphasizes teachers' active and independent engagement in developing digital competence. Within this

perspective, Digital Self-Learning is not merely a complementary activity but may serve as a core mechanism for translating institutional conditions into actual pedagogical practice.

Although prior studies have examined institutional support, professional development, and digital competence separately, limited research has integrated these factors into a unified behavioral framework explaining how teachers translate institutional conditions into classroom-level ICT integration. Building on this reasoning, this study proposes a reconceptualization of ICT integration as a behaviorally driven process, in which Digital Self-Learning serves as the central driver linking institutional conditions and professional outcomes.

Specifically, Institutional Support is expected to facilitate teachers' engagement in Digital Self-Learning by providing enabling conditions such as infrastructure, leadership encouragement, and access to training opportunities. However, rather than directly influencing classroom practice, its impact is expected to operate indirectly through teachers' self-directed learning behaviors.

Furthermore, Digital Self-Learning is expected to contribute to Professional Development, as teachers who actively engage in autonomous learning are more likely to participate in structured training, professional networks, and collaborative learning activities. In this sense, Professional Development can be understood as a formalization and amplification of self-directed learning processes, translating individual competence into structured professional growth.

At the classroom level, both Digital Self-Learning and Professional Development are expected to influence Technology Integration. Digital Self-Learning enables teachers to experiment with digital tools, adapt pedagogical strategies, and implement innovative practices independently, while Professional Development supports the systematic alignment of technology use with curriculum and instructional goals. Together, these mechanisms form a pathway through which individual learning behavior is translated into effective ICT integration.

In contrast, teacher-related demographic attributes, including age, gender, and level of education, are treated as control variables rather than primary predictors. Although prior studies have reported mixed findings regarding their influence on digital competence, recent evidence suggests that their effects are relatively limited compared to behavioral and institutional factors (Mulyanti et al., 2024; Suzer & Koc, 2024).

Grounded in this theoretical framework, the research formulates several hypotheses, namely:

H1. Digital Self-Learning positively influences Professional Development.

H2. Digital Self-Learning positively influences Technology Integration.

H3. Institutional Support positively influences Digital Self-Learning.

H4. Institutional Support positively influences Technology Integration.

H5. Institutional Support indirectly influences Technology Integration through Digital Self-Learning.

H6. Professional Development positively influences Technology Integration.

Taken together, the proposed model conceptualizes ICT integration as a behaviorally driven, multi-level process in which institutional conditions foster teachers' autonomous digital learning behaviors, which subsequently strengthen professional development and translate into meaningful classroom-level technology integration.

RESULTS AND DISCUSSION

Result

a. Evaluation of the Measurement Model

Referring to established methodological guidelines (Hair et al., 2019), the study examines indicator reliability, construct reliability, convergent validity, discriminant validity, and formative construct evaluation to assess the measurement model.

1. Indicator Reliability

Table 3 presents the outer loadings of the measurement items. Most indicators exceeded the recommended level of 0.70, confirming their reliability in representing the latent constructs. Digital Self-Learning (DS1–DS5) ranged from 0.811 to 0.874, while Professional Development (PD1–PD3) ranged from 0.820 to 0.848. Technology Integration mostly exceeded 0.74, peaking at 0.872.

However, one indicator was below the recommended threshold of 0.70: TI1 (0.662). Refer to (Hair et al., 2019), indicators with outer loadings ranging from 0.40 to 0.70 can be retained when deleting them does not enhance the construct's convergent validity, and the Average Variance Extracted (AVE) remains above the recommended 0.50 threshold. Since the AVE of the Technology Integration construct exceeded the recommended value, TI1 was retained for further analysis. Overall, the reflective measurement indicators demonstrated satisfactory indicator reliability.

Table 3. Outer Loadings of Measurement Items

Constructs	Age	Gender	Education	Digital Self-Learning	Professional Development	Technology Integration
Age	1.000					
Gender		1.000				
Education			1.000			
DS1				0.821		
DS2				0.867		
DS3				0.811		
DS4				0.819		
DS5				0.874		
PD1					0.848	
PD2					0.835	
PD3					0.820	
TI1						*0.662*
TI10						0.872
TI11						0.831
TI12						0.860
TI13						0.838
TI14						0.827
TI2						0.744
TI3						0.796
TI4						0.740
TI5						0.767
TI6						0.833
TI7						0.831
TI8						0.812
TI9						0.838

1. Reliability and Convergent Validity

Table 4 reports the results for construct reliability and convergent validity. Construct reliability was assessed using Cronbach's Alpha and Composite Reliability (CR). All three constructs (Digital Self-Learning, Professional Development, and Technology Integration) exceeded the minimum threshold of 0.70, demonstrating satisfactory internal consistency (Hair et al., 2019). Moreover, convergent validity was evaluated based on the AVE, with all constructs exceeding the recommended 0.50 threshold (Sohu et al., 2024). These findings provide support for acceptable internal consistency and convergent validity. Collectively, these outcomes show that the subsequent structural model assessment is based on a reliable and valid measurement foundation.

Table 4. Construct Reliability and Validity (CA, CR, AVE)

Construct	Cronbach's Alpha	Composite Reliability (ρA)	Composite Reliability (ρC)	AVE
Digital Self-Learning	0.894	0.896	0.922	0.703
Professional Development	0.786	0.800	0.873	0.697
Technology Integration	0.958	0.960	0.963	0.649

2. Discriminant Validity

The study used two steps to measure discriminant validity. First, discriminant validity was assessed using the Fornell–Larcker criterion (Sohu et al., 2024) by associating the square root of the AVE with the correlations among constructs. As shown in Table 5, the square root of the AVE for each construct, shown on the diagonal, consistently exceeded the corresponding inter-construct correlations reported off the diagonal, indicating satisfactory discriminant validity. The constructs of Digital Self-Learning, Professional Development, and Technology Integration were empirically distinct, even though they were correlated.

Table 5. Fornell–Larcker Criterion

Construct	Age	Gender	Education	Digital Self-Learning	Professional Development	Technology Integration
Age	1.000					
Gender	0.058	1.000				
Education	-0.315	0.052	1.000			
Digital Self-Learning	-0.005	-0.030	-0.032	0.839		
Professional Development	0.037	0.144	-0.030	0.695	0.835	
Technology Integration	0.081	0.084	0.021	0.788	0.750	0.806

Note: Diagonal values are √AVE; off-diagonals are latent-variable correlations.

Second, the Heterotrait–Monotrait ratio (HTMT) was evaluated as suggested by (Cheung et al., 2024). The results in Table 6 indicate that all HTMT values remained below the conventional 0.90 threshold, with the highest value identified between Digital Self-Learning and Technology Integration (0.849). These results offer additional support for the empirical distinction of the constructs.

Table 6. HTMT Matrix

Construct	Age	Gender	Education	Digital Self-Learning	Professional Development	Technology Integration
Age	—					
Gender	0.058	—				
Education	0.315	0.052	—			
Digital Self-Learning	0.072	0.034	0.036	—		
Professional Development	0.107	0.163	0.038	0.803	—	
Technology Integration	0.080	0.089	0.088	0.849	0.843	—

Overall, the Fornell–Larcker criterion and HTMT results indicate that the measurement model achieves acceptable discriminant validity. This strengthens confidence that the constructs capture unique features of teachers' digital practices. Therefore, it reduces the risk of conceptual overlap and supports the robustness of the measurement model.

3. Formative Construct Assessment

Institutional Support was specified as a formative construct and evaluated in accordance with (Hair et al., 2019) recommendations. Unlike reflective constructs, formative constructs are primarily assessed by the significance of outer weights and the absence of multicollinearity, rather than by internal consistency measures. As presented in Table 7, IS3 (school leaders encourage teachers to adopt digital technologies) exhibited a statistically significant outer weight (β = 0.742, t = 3.416, p = 0.001), demonstrating that leadership support made a substantial contribution to the formation of Institutional Support. In contrast, IS1 (reliable internet access) and IS2 (regular digital training opportunities) produced non-significant outer weights (p > 0.05). Following (Hair et al., 2019), the outer loadings of these items were subsequently examined to evaluate their absolute contribution to the construct.

Table 7. Formative Measurement Assessment of Institutional Support

Indicator	Outer Weight	*t*-value	*p*-value	Outer Loading	VIF
IS1: My school provides reliable internet access	0.374	1.423	0.155	0.267	1.071
IS2: My school offers regular digital training opportunities	0.385	1.378	0.168	0.522	1.075
IS3: School leaders encourage teachers to adopt digital technologies	0.742	3.416	0.001	0.917	1.085

Note. Outer weights were measured using bootstrapping with 5,000 resamples. Following Hair et al. (2022), outer loadings were examined as complementary evidence to assess the absolute contribution of indicators when outer weights were not statistically significant. All VIF values were below the recommended threshold of 3.3, demonstrating the absence of multicollinearity among the formative indicators.

The results showed that IS2 demonstrated an acceptable outer loading (0.522), whereas IS1 exhibited a relatively low loading (0.267), indicating that the indicators contributed to the construct to different degrees. Nevertheless, (Hair et al., 2019) emphasize that formative indicators should not be eliminated solely because their outer weights are statistically non-significant, particularly when they represent conceptually distinct dimensions of the construct. In the present study, reliable internet access, digital training opportunities, and leadership encouragement represent three complementary facets of institutional support that collectively define the construct. These dimensions capture infrastructure, capacity-building, and managerial support, respectively. Eliminating any of these indicators would reduce the conceptual coverage of Institutional Support and weaken its content validity. Therefore, all three indicators were retained in the final measurement model to preserve the construct's theoretical integrity.

Multicollinearity among the formative indicators was assessed using the Variance Inflation Factor (VIF). As shown in Table 7, all VIF values ranged from 1.071 to 1.085, substantially below the conventional threshold of 3.3, as per (Hair et al., 2019). This indicates that multicollinearity is not problematic and that each indicator captures distinct information in shaping the formative construct.

Overall, the measurement model assessment shows that the construct satisfies the required standards for reliability and validity. Most of the indicators have strong outer loadings that are above the recommended value of 0.7, except items (IS1, IS2, and TI1). Following (Hair et al., 2019), the study retained IS2 and TI1 because their AVEs were satisfactory; however, IS1 was removed to ensure acceptable convergent validity. The study concludes that the constructs exhibit higher reliability, as confirmed by Cronbach's Alpha and Composite Reliability. Convergent validity was established because all AVE values were above 0.50. Discriminant validity was assessed using the Fornell–Larcker criterion and HTMT ratios. Both values support that the constructs are empirically distinct. The measurement model shows no major multicollinearity problems, as all VIF values are below 5.0. The study concludes that the measurement model is adequate for further structural model analysis.

b. Structural Model Evaluation

The study examines the proposed relationship among the constructs by estimating a structural model. Analyses were performed by testing for collinearity (VIF), estimating path coefficients and their

significance via bootstrapping, and assessing the coefficient of determination (R^2), effect size (f^2), and predictive relevance (Q^2) (Hair et al., 2019). The results from PLS-SEM, including path coefficients, R^2 for the endogenous constructs, and outer loadings of the observed indicators, are presented in Figure 2. The figure presents the model's explanatory power and the strength of relations among concepts, followed by a statistical summary.

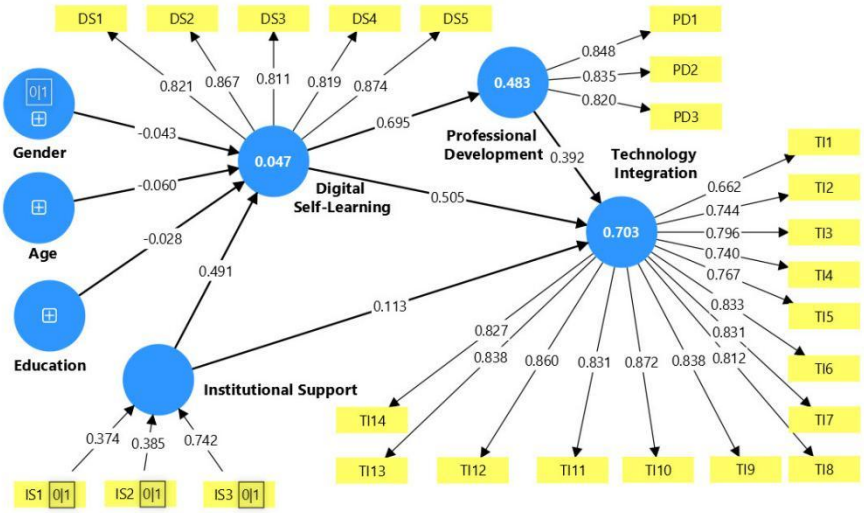

Figure 2. PLS-SEM results with path coefficients, R^2 values, and indicator loadings

1. Collinearity Assessment

VIF is assessed in this study to confirm that the estimated path coefficients are not biased by multicollinearity. Table 8 provides the inner VIF values for the endogenous constructs: Digital Self-Learning, Professional Development, and Technology Integration. Multicollinearity among the predictor constructs is assessed using VIFs.

Table 8. Inner VIF Values

Endogenous Construct	Predictor(s)	VIF
Digital Self-Learning	Age	1.164
Digital Self-Learning	Education	1.118
Digital Self-Learning	Gender	1.010
Digital Self-Learning	Institutional Support	1.053
Professional Development	Digital Self-Learning	1.000
Technology Integration	Digital Self-Learning	1.982
Technology Integration	Institutional Support	1.045
Technology Integration	Professional Development	1.933

Given the suggested threshold of 5.0 (Hair et al., 2019) and the conventional cut-off of 3, the study concludes that the structural model exhibits no multicollinearity. Therefore, the path coefficients can be interpreted without bias.

2. Coefficient of Determination (R^2)

The explanatory power of the model was evaluated using the coefficient of determination (R^2). Table 9 summarizes the results.

Table 9. R^2 Values of Endogenous Constructs

Construct	R^2	R^2 Adjusted
Digital Self-Learning	0.047	0.030
Professional Development	0.483	0.480
Technology Integration	0.703	0.699

Guideline, R^2 values of 0.67, 0.33, and 0.19 are considered substantial, moderate, and weak, respectively. This classification has been widely adopted in subsequent PLS-SEM literature (Hair et al., 2019). Digital Self-Learning has a relatively low R^2 of 0.047, indicating that demographic factors and institutional support explain only a small portion of its variance. In contrast, Professional Development achieved a moderate R^2 of 0.483, demonstrating that nearly half of its variance is explained by Digital Self-Learning. The strongest explanatory power was found for Technology Integration, with an R^2 of 0.703, which is considered substantial according to(Peng et al., 2023).

The result confirms that Digital Self-Learning, Professional Development, and Institutional Support explain more than 70% of the variance in Technology Integration. However, Professional Development demonstrates moderate explanatory power (R^2 = 0.483), indicating that Digital Self-Learning accounts for nearly half of its variance. In contrast, Digital Self-Learning exhibits weak explanatory power (R^2 = 0.047), indicating that demographic and institutional predictors (Age, Gender, Education, Institutional Support) explain only a limited proportion of its variance.

3. Path Coefficients and Hypotheses Testing

The study evaluated the importance of the hypothesized relationships using a bootstrapping procedure with 5,000 resamples and a two-tailed test at the 95% confidence level. Table 10 summarizes the path coefficients (β), t-values, p-values, and the decision for each control variable and hypothesis.

Table 10. Hypotheses Testing Results

Hypothesis	Path	β	t-value	p-value	Decision
Control	Age → Digital Self-Learning	-0.060	0.959	0.338	Not Significant
Control	Gender → Digital Self-Learning	-0.043	0.309	0.757	Not Significant
Control	Education → Digital Self-Learning	-0.028	0.357	0.721	Not Significant
H1	Digital Self-Learning → Professional Development	0.695	22.528	0.000	Supported
H2	Digital Self-Learning → Technology Integration	0.505	9.341	0.000	Supported
H3	Institutional Support → Digital Self-Learning	0.491	3.222	0.001	Supported
H4	Institutional Support → Technology Integration	0.113	1.240	0.215	Not Supported
H5	Institutional Support → Digital Self-Learning→ Technology Integration	0.248	2.929	0.003	Supported
H6	Professional Development → Technology Integration	0.392	7.145	0.000	Supported

The results of hypothesis testing provide several important insights. First, the control variables age, gender, and educational level did not significantly predict Digital Self-Learning ($p > 0.05$). These results indicate that teachers' involvement in digital self-learning is not determined by demographic characteristics but is more strongly associated with behavioral and contextual factors.

Second, Digital Self-Learning demonstrated strong and highly significant positive effects on both Professional Development ($\beta = 0.695$, $p < 0.001$) and Technology Integration ($\beta = 0.505$, $p < 0.001$), supporting H1 and H2. These findings underscore the central role of Digital Self-Learning in enhancing teachers' professional growth and the integration of classroom technology.

Third, Institutional Support had a significant positive effect on Digital Self-Learning ($\beta = 0.491$, $p = 0.001$), supporting H3. However, its direct effect on Technology Integration was not significant ($\beta = 0.113$, $p = 0.215$), so H4 was not supported. This finding recommends that institutional support alone is insufficient to directly improve teachers' technology integration practices.

Fourth, the mediation analysis revealed that Institutional Support employed a significant indirect effect on Technology Integration through Digital Self-Learning (β = 0.248, p = 0.003), supporting H5. This result indicates that Institutional Support contributes to Technology Integration primarily by encouraging teachers to engage in continuous Digital Self-Learning rather than through a direct pathway.

Finally, Professional Development significantly strengthened Technology Integration (β = 0.392, p < 0.001), supporting H6. Taken together, these findings demonstrate that Digital Self-Learning is the primary mechanism linking Institutional Support to Technology Integration, while demographic characteristics play a limited role in explaining teachers' digital learning behavior.

4. Effect Size (f^2)

Effect size (f^2) was estimated to determine the extent to which each exogenous construct contributes to the R^2 of its related endogenous construct. Based on (Hair et al., 2019), f^2 values of 0.02, 0.15, and 0.35 represent small, medium, and large effects, respectively. As presented in Table 11, the calculated f^2 values demonstrate the relative influence of each predictor construct in accounting for the variance of its corresponding endogenous construct.

Table 11. Effect Size (f^2) Results

Endogenous Construct	Predictor	f^2	Interpretation
Digital Self-Learning	Age	0.003	Negligible
Digital Self-Learning	Education	0.001	Negligible
Digital Self-Learning	Gender	0.000	Negligible
Digital Self-Learning	Institutional Support	0.047	Small
Professional Development	Digital Self-Learning	0.932	Large
Technology Integration	Digital Self-Learning	0.433	Large
Technology Integration	Institutional Support	0.008	Negligible
Technology Integration	Professional Development	0.268	Medium

The effect size analysis offers more insights into the relative importance of the model's constructs. Digital Self-Learning has a significant impact on Professional Development (f^2 = 0.932), underscoring its critical role in shaping teachers' professional growth. Similarly, Digital Self-Learning also demonstrates a significant effect on Technology Integration (f^2 = 0.433), further confirming the central importance of teachers' self-directed learning in driving classroom technology adoption. Professional Development contributes to Technology Integration with a medium effect (f^2 = 0.268), indicating that while formal training and structured development programs are valuable, their influence is not as strong as that of self-learning. Institutional Support shows a small but meaningful effect on Digital Self-Learning (f^2 = 0.047), indicating that supportive environments encourage teachers' engagement in independent digital learning. In contrast, the direct effect of Institutional Support on Technology Integration (f^2 = 0.008) and the contributions of demographic predictors Age, Gender, and Education to Digital Self-Learning (f^2 < 0.01) are negligible.

Taken together, these results reinforce the conclusion that Digital Self-Learning is the primary driver of both Professional Development and Technology Integration. Institutional support exerts its influence indirectly through self-learning, rather than directly on technology practices, while demographic characteristics have only a limited influence within the process. These findings emphasize the influence of promoting self-directed learning to enhance both teachers' professional growth and their integration of digital technologies in the classroom.

5. Predictive Relevance (Q^2_predict)

The model's predictive relevance was assessed using PLSpredict with 10-fold cross-validation. Table 12 summarizes the Q^2_predict, RMSE, and MAE values for each endogenous construct.

Table 12. PLSpredict Results (Latent Variable Summary)

Construct	Q^2_predict	RMSE	MAE	Interpretation
Digital Self-Learning	-0.194	1.100	0.889	No predictive relevance
Professional Development	-0.104	1.061	0.906	No predictive relevance
Technology Integration	-0.200	1.106	0.912	No predictive relevance

The study employed PLSpredict to evaluate the model's predictive relevance. The results show that all Q^2_predict values were negative, indicating that the model demonstrated limited out-of-sample predictive capability. In PLS-SEM, Q^2 predict values above zero indicate predictive relevance, whereas negative values suggest that the model does not predict new observations better than the benchmark model (Hair et al., 2019). Although the model exhibited weak predictive performance, the relatively high R^2 value for Technology Integration (0.703) indicates substantial explanatory power. Therefore, the proposed model is more suitable for explanatory and theory-development purposes than for predictive forecasting. Consequently, while the model offers useful insights into the determinants shaping teachers' Technology Integration, its limited out-of-sample predictive capability suggests caution when applying the findings to predict teacher behavior in different educational settings or populations. Further validation using independent datasets and diverse educational contexts is recommended to improve the model's predictive performance.

6. Model Fit

The study emphasizes evaluating the measurement model (construct reliability and validity) and the structural model (R^2, f^2, Q^2_predict, and path significance) to evaluate model fit. Refer to (Hair et al., 2019) suggestions, the study focused on the reliability and validity of the constructs, the model's explanatory power (R^2), the effect sizes (f^2), the predictive relevance (Q^2_predict), and the significance of hypothesized paths obtained through bootstrapping. These evaluations provide sufficient evidence that the model establishes acceptable explanatory power and adequate predictive performance, even though global fit indices were not reported.

Discussion

1. Digital Self-Learning as the Primary Driver of Technology Integration

The findings demonstrate that Digital Self-Learning (DSL) is the strongest predictor of both Professional Development ($\beta = 0.695$, $p < 0.001$) and Technology Integration ($\beta = 0.505$, $p < 0.001$), demonstrating that teachers' autonomous learning behavior plays a more influential role in ICT integration than institutional support or demographic characteristics. This finding extends previous studies that highlight the importance of self-directed learning in developing teachers' digital competence (Caena & Redecker, 2019; Linde et al., 2023). While previous studies have generally regarded Digital Self-Learning as a complementary component of professional development, the present study demonstrates that it serves as the primary behavioral mechanism by which teachers continuously strengthen both their professional competence and their classroom technology integration. These results suggest that sustainable ICT integration depends less on formal training and more on teachers' ability to independently acquire, evaluate, and apply emerging digital knowledge in authentic instructional contexts.

This finding is especially pertinent to the Indonesian educational setting. The employment of the Merdeka Curriculum encourages teachers to continuously adapt their instructional practices to rapidly evolving digital technologies. However, opportunities for formal ICT training remain uneven across schools due to disparities in geographical location, institutional resources, and financial capacity. Consequently, many teachers increasingly rely on self-directed learning through webinars, online tutorials, professional learning communities, social media, and AI-assisted learning tools to continuously update their digital competencies. These informal learning environments provide immediate, practice-oriented solutions that can be directly implemented in classroom instruction. This reflects the emergence of a broader digital learning ecosystem in which teachers are no longer passive recipients of institutional knowledge but rather active participants in collaborative, technology-mediated knowledge networks. Similar developments have been observed internationally, where professional learning increasingly occurs through online communities, open

educational resources, and networked collaboration rather than exclusively through centralized training programs.

The stronger influence of Digital Self-Learning than of Professional Development also provides empirical support for recent critiques of conventional top-down ICT professional development practice (Amemasor et al., 2025; Khoiro et al., 2025). Traditional professional development is frequently delivered through standardized workshops with predetermined content and limited follow-up, making it difficult to accommodate teachers' diverse classroom contexts and rapidly changing technological needs. In contrast, Digital Self-Learning is continuous, personalized, and immediately applicable. Teachers can identify instructional challenges, explore relevant digital solutions, experiment with emerging technologies, and directly evaluate their effectiveness in classroom practice. This continuous cycle of learning, application, and reflection enables teachers to develop practical digital competencies that are more readily translated into meaningful technology integration.

From a theoretical perspective, the findings reconceptualize Digital Self-Learning as the primary behavioral mechanism that links teachers' individual agency to sustainable technology integration. Existing ICT integration models have predominantly emphasized institutional provision, technological infrastructure, or formal professional development as the principal drivers of digital competence. In contrast, this study suggests that institutional resources create opportunities for learning, but their educational value depends largely on teachers' willingness to transform those opportunities into continuous self-directed learning. This perspective complements the DigCompEdu framework (Christine, 2017) by highlighting that teachers' digital competence evolves not only through institutional interventions but also through ongoing engagement with dynamic digital ecosystems. Accordingly, the study advances a more behaviorally oriented perspective on ICT integration, in which sustainable digital transformation is driven primarily by teachers' capacity for continuous learning rather than by organizational support alone.

2. Institutional Support as an Enabler Rather Than a Direct Driver

Another important finding is that Institutional Support did not directly influence Technology Integration but exerted a substantial positive effect on Digital Self-Learning. This proposes that institutional resources alone are insufficient to promote meaningful technology integration unless they first stimulate teachers' autonomous learning behaviors. Rather than directly determining classroom technology use, Institutional Support creates conditions that enable teachers to continuously develop the digital competencies required for effective instructional practice. This finding extends previous ICT integration studies, which have generally emphasized infrastructure, institutional policies, technical assistance, and formal professional development as direct drivers of technology adoption (Amemasor et al., 2025; Wiyono et al., 2024). The study instead indicates that institutional resources become educationally valuable only when teachers actively transform them into continuous learning experiences through Digital Self-Learning.

The Indonesian educational context provides a plausible explanation for this indirect relationship. Although the implementation of the Merdeka Curriculum has accelerated investment in digital infrastructure, internet connectivity, and school-based digital initiatives, these resources do not automatically translate into effective classroom technology integration. Teachers must still independently explore digital platforms, experiment with instructional technologies, and adapt new knowledge to diverse classroom contexts. Consequently, institutional support functions primarily as a facilitating environment rather than a direct mechanism of change. This interpretation is in line with recent organizational learning literature, which highlights that organizational resources create value only when learning is effectively transferred into practice and translated into everyday work activities (Zarina et al., 2023).

The findings, therefore, suggest that educational digital transformation should move beyond an infrastructure-centered perspective toward a learning ecosystem perspective. Investments in hardware, connectivity, and institutional policies remain necessary, but they should be accompanied by organizational cultures that encourage curiosity, experimentation, collaboration, and continuous learning. Schools should create environments that encourage teachers to participate in professional learning communities, engage in peer mentoring, share digital teaching practices, and experiment

with emerging technologies, including artificial intelligence. Such initiatives strengthen the indirect pathway through which Institutional Support enhances Technology Integration by fostering sustained Digital Self-Learning.

From a theoretical perspective, this study reconceptualizes Institutional Support as an enabling contextual factor rather than a direct organizational driver of technology integration. Institutional resources create opportunities for learning, whereas Digital Self-Learning determines the extent to which these opportunities are translated into meaningful classroom practice. This perspective complements existing ICT integration literature by demonstrating that organizational conditions and teachers' individual agency operate as mutually reinforcing mechanisms rather than competing explanations. Accordingly, sustainable digital transformation depends not only on institutional investment but also on teachers' continuous capacity to learn, adapt, and innovate within increasingly dynamic digital learning ecosystems.

3. Why Demographic Characteristics Matter Less in Technology Integration

An additional finding of this study is that demographic characteristics, including age, gender, and educational attainment, did not significantly influence teachers' Digital Self-Learning or Technology Integration. This suggests that demographic differences are no longer the primary determinants of teachers' digital competence. Instead, behavioral factors particularly teachers' willingness to continuously learn and adapt through Digital Self-Learning play a more influential role in shaping technology integration. Although previous studies have reported mixed evidence regarding the effects of age, gender, and educational background on educational technology adoption (Mulyanti et al., 2024; Suzer & Koc, 2024), the present findings indicate that these demographic distinctions are becoming less influential within increasingly connected digital learning environments.

One explanation is the democratization of digital learning opportunities. Unlike earlier periods when professional learning relied primarily on formal institutional programs, teachers today have broad access to online learning platforms, webinars, open educational resources, professional online communities, and AI-assisted learning tools. As these resources become more accessible, opportunities to develop digital competence are increasingly available regardless of teachers' demographic backgrounds. Within the Indonesian educational context, the implementation of the Merdeka Curriculum has further accelerated this trend by encouraging teachers across different generations to continuously update their instructional practices. Consequently, successful technology integration depends less on demographic characteristics and more on teachers' learning orientation, openness to innovation, and capacity for continuous self-directed learning.

The findings further suggest that the digital divide within schools may be shifting from demographic disparities toward behavioral disparities. Rather than distinguishing teachers by age, gender, or educational qualifications, the more meaningful distinction lies between teachers who actively engage in continuous Digital Self-Learning and those who rely primarily on formal institutional training. This perspective explains why Digital Self-Learning emerged as a substantially stronger predictor of Technology Integration than any demographic variable included in the model and supports the growing recognition that lifelong learning has become a fundamental competency for educators in digitally transforming educational systems.

From both theoretical and practical perspectives, these results suggest that behavioral adaptability increasingly outweighs demographic characteristics in explaining teachers' technology integration. Existing ICT adoption models have frequently incorporated demographic variables as important antecedents of technology use; however, the present study indicates that their explanatory power may be diminishing within contemporary digital ecosystems. Accordingly, schools and policymakers should prioritize initiatives that strengthen Digital Self-Learning across all teacher groups by expanding equitable access to digital learning resources, fostering collaborative professional learning communities, and promoting continuous professional learning rather than designing interventions primarily based on demographic categories.

Implications

This study proposes significant implications for both theoretical development and practical implementation. Theoretically, the study advances ICT integration research by proposing a more

behaviorally oriented perspective on educational digital transformation. Rather than emphasizing institutional support, technological infrastructure, or formal professional development as the primary drivers of technology adoption, the findings position Digital Self-Learning as the central behavioral mechanism through which teachers develop digital competence and translate it into meaningful classroom technology integration. At the same time, Institutional Support is reconceptualized as an enabling contextual condition that creates opportunities for learning rather than functioning as a direct determinant of technology integration. Together, these findings suggest that sustainable digital transformation emerges through the interaction between organizational support and teachers' autonomous learning behavior. Furthermore, the limited influence of demographic characteristics indicates that future ICT integration research should place greater emphasis on dynamic behavioral constructs than on relatively stable personal characteristics.

From a practical perspective, the findings indicate that schools should move beyond infrastructure-oriented and training-centered approaches to digital transformation. While reliable internet access, institutional policies, and professional development remain important, they should be complemented by organizational cultures that encourage continuous Digital Self-Learning. Schools can strengthen teachers' digital competence by supporting collaborative professional learning communities, peer mentoring, access to digital learning resources, and opportunities to experiment with emerging educational technologies, including artificial intelligence. Rather than evaluating teachers solely through participation in formal training programs, school leaders should recognize continuous self-directed learning as an integral component of professional growth.

The findings also carry important implications for educational policymakers. Current teacher professional development policies often emphasize centralized and standardized ICT training. Although such initiatives remain valuable, they should be complemented by more flexible, teacher-driven learning opportunities, including open digital learning platforms, online professional communities, and micro-credential programs that support lifelong learning. Such initiatives would enable teachers to continuously update their digital competencies in response to rapidly evolving educational technologies rather than relying exclusively on periodic institutional training.

Overall, the study suggests that successful educational digital transformation should be viewed not simply as a technological or infrastructural initiative but as a continuous learning process. Sustainable technology integration depends not only on institutional investment but also on teachers' capacity for lifelong learning, continuous adaptation, and active participation in dynamic digital learning ecosystems. This perspective provides a more comprehensive framework for understanding how schools can achieve sustainable ICT integration in the era of rapid digital transformation and artificial intelligence.

Research Contributions

This study makes several contributions to the literature on ICT integration and teacher digital competence. First, it advances existing research by positioning Digital Self-Learning as the primary behavioral mechanism underlying Technology Integration. While previous studies have largely emphasized formal professional development, institutional support, or technological infrastructure as the principal drivers of ICT adoption, the present findings demonstrate that teachers' continuous self-directed learning plays a more influential role in developing digital competence and facilitating sustainable classroom technology integration.

Second, the study reconceptualizes Institutional Support as an enabling contextual condition rather than a direct determinant of Technology Integration. The findings indicate that institutional resources, including infrastructure, leadership encouragement, and professional learning opportunities, create favorable conditions for digital transformation but exert their greatest influence by fostering teachers' Digital Self-Learning. This behavioral pathway provides a more comprehensive explanation of how organizational support translates into meaningful instructional practice.

Third, the study contributes to the growing body of literature suggesting that behavioral adaptability increasingly outweighs demographic characteristics in explaining teachers' technology integration. As access to digital learning resources becomes more widespread, age, gender, and educational attainment appear to have less explanatory power than teachers' willingness to continuously learn,

adapt, and engage with evolving digital technologies. This finding supports a shift from demographic-centered explanations toward behavioral models of ICT integration.

Finally, the study provides empirical evidence from Indonesia, a developing country context where disparities in infrastructure and professional learning opportunities remain evident. By integrating Digital Self-Learning, Institutional Support, Professional Development, and demographic characteristics into a single explanatory framework, the study offers a more holistic understanding of how teachers develop digital competence within contemporary educational digital ecosystems. This framework contributes to ongoing discussions on sustainable digital transformation by emphasizing that technology integration is fundamentally a continuous learning process rather than merely the outcome of technological investment or institutional intervention.

Limitations

This study has several limitations. First, the cross-sectional design and reliance on self-reported data from Indonesian teachers limit causal inference and the generalizability of the findings. Second, the study relied exclusively on quantitative data, which may not fully capture teachers' experiences and contextual challenges in developing Digital Self-Learning and integrating technology into classroom practice. Third, Institutional Support was operationalized through three dimensions infrastructure availability, digital learning opportunities, and leadership encouragement and therefore may not fully capture broader organizational aspects such as ICT policies, technical support, and an organizational culture of innovation. Finally, although the proposed model demonstrated substantial explanatory power, the negative PLSpredict (Q^2_predict) values indicate limited out-of-sample predictive performance. Accordingly, the proposed framework should be interpreted primarily as an explanatory rather than a predictive model.

Suggestions

Future research is encouraged to validate the proposed framework through longitudinal, cross-cultural, and mixed-methods designs to deepen understanding of teachers' Digital Self-Learning and Technology Integration. Further studies may expand the model by incorporating additional behavioral and organizational factors, including broader dimensions of Institutional Support, such as ICT policies, technical support services, and an organizational culture of innovation, and by examining the role of emerging technologies, particularly artificial intelligence. Finally, validating the framework across diverse educational settings and improving its predictive capability would further strengthen its theoretical robustness and practical applicability.

CONCLUSION

This study developed and empirically validated an integrated model explaining Technology Integration among Indonesian teachers by examining the relationships among Digital Self-Learning, Institutional Support, Professional Development, and demographic characteristics using PLS-SEM. The findings demonstrate that Digital Self-Learning is the strongest determinant of both Professional Development and Technology Integration, while Institutional Support influences Technology Integration indirectly by fostering teachers' Digital Self-Learning. In contrast, demographic characteristics were found to have only a limited influence on teachers' digital competence and technology integration practices.

The study advances the ICT integration literature by proposing a behavioral perspective of educational digital transformation. Rather than viewing technology integration primarily as the outcome of technological infrastructure or formal professional development, the findings suggest that sustainable ICT integration is fundamentally driven by teachers' continuous capacity to independently acquire, adapt, and apply digital competencies within dynamic digital learning ecosystems. Institutional Support, therefore, functions as an enabling condition that facilitates continuous learning, whereas Digital Self-Learning represents the key behavioral mechanism by which organizational support translates into meaningful classroom technology integration.

From a practical perspective, the findings suggest that schools and policymakers should complement infrastructure investment and formal professional development with strategies that cultivate

continuous Digital Self-Learning. Building collaborative professional learning communities, expanding access to digital learning resources, and encouraging teachers' autonomous engagement with emerging technologies, including artificial intelligence, are likely to support more sustainable and adaptive technology integration. Overall, this study highlights that successful educational digital transformation depends not only on technological investment but also on teachers' capacity for lifelong learning and their ongoing willingness to learn, adapt, and innovate.

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AUTHOR CONTRIBUTION STATEMENT

HP conceived and designed the study, developed the research methodology, interpreted the findings, wrote and revised the manuscript, and approved the final version. SS coordinated the data collection process, assisted in data processing, conducted reference checking, contributed to the writing of the Introduction section, and reviewed the manuscript.

AI DISCLOSURE STATEMENT

All conceptual development, data analysis, interpretation of findings, and final scientific decisions were conducted solely by the authors. The authors used ChatGPT and Grammarly to refine the language, conduct structural editing, and enhance academic writing during the preparation of this manuscript. After using these tools, the authors thoroughly reviewed, revised, and verified the manuscript for the accuracy, originality, and integrity of the final published work.

CONFLICTS OF INTEREST

The authors declares no conflicts of interest regarding financial, institutional, or personal interests in this study that may have influenced the results of the study.

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