

The Influence of Managerial Support and ICT Facility Availability on Learning Effectiveness Through Teacher Digital Competence in State Senior High Schools (SMA Negeri) in Pandeglang Regency

¹⁾ Nono Suhada, ²⁾ Furtasan Ali Yusuf, ³⁾ Ika Pratiwi

^{1, 2, 3)} Universitas Bina Bangsa

*Corresponding author: nonosuhada14@gmail.com

Article Information

Keywords:

managerial support; ICT facilities; teacher digital competence; learning effectiveness; SEM-PLS

ABSTRACT

Purpose: This study aims to examine the effects of managerial support and ICT facility availability on learning effectiveness, both directly and through teacher digital competence as a mediating variable, among teachers at State Senior High Schools (SMA Negeri) in Pandeglang Regency, Banten Province. **Research Methodology:** This study used a quantitative correlational design. Data were collected from 161 permanent teachers across five State Senior High Schools in Pandeglang Regency, selected through proportionate stratified random sampling from a population of 269 teachers. A structured five-point Likert-scale questionnaire was administered to measure managerial support, ICT facility availability, teacher digital competence, and learning effectiveness. Data were analyzed using Structural Equation Modeling with Partial Least Squares (SEM-PLS) with bootstrap resampling of 5,000 iterations. **Results:** The findings show that managerial support and ICT facility availability each have a positive and significant effect on learning effectiveness and teacher digital competence. Teacher digital competence also has a positive and significant effect on learning effectiveness and partially mediates the relationship between the two exogenous variables and learning effectiveness. The structural model explains 69.1% of the variance in teacher digital competence and 73.4% of the variance in learning effectiveness, with good model fit (SRMR = 0.036). **Conclusions:** Managerial support and ICT facilities jointly strengthen learning effectiveness, and this influence is reinforced through improvements in teacher digital competence, which functions as the central link connecting institutional support and technological resources with classroom learning quality. **Limitations:** This study used a cross-sectional design with self-reported data from a sample limited to five public schools in one regency; therefore, the findings cannot yet be broadly generalized to other regions or school types. **Contribution:** This study offers practical guidance for school principals and education policymakers in Pandeglang Regency and similar regions in designing managerial support strategies and ICT facility investments aimed at strengthening teacher digital competence as a key lever for improving learning effectiveness.

Article Information

Keywords:

dukungan manajerial; fasilitas TIK; kompetensi digital guru; efektivitas pembelajaran; SEM-PLS

ABSTRACT

Penelitian ini bertujuan untuk menguji pengaruh dukungan manajerial dan ketersediaan fasilitas teknologi informasi dan komunikasi (TIK) terhadap efektivitas pembelajaran, baik secara langsung maupun melalui kompetensi digital guru sebagai variabel mediasi, pada guru SMA Negeri di Kabupaten Pandeglang, Provinsi Banten. Penelitian menggunakan pendekatan kuantitatif korelasional dengan melibatkan 161 guru tetap dari lima SMA Negeri, yang dipilih melalui teknik proportionate stratified random sampling dari populasi 269 guru. Data dikumpulkan menggunakan kuesioner skala Likert lima poin dan dianalisis dengan Structural Equation Modeling berbasis Partial Least Squares (SEM-PLS) melalui bootstrap 5.000 kali replikasi. Hasil penelitian menunjukkan bahwa dukungan manajerial dan fasilitas TIK masing-masing berpengaruh positif dan signifikan terhadap efektivitas pembelajaran maupun terhadap kompetensi digital guru. Kompetensi digital guru juga terbukti berpengaruh positif signifikan terhadap efektivitas pembelajaran dan berperan sebagai mediator parsial dalam hubungan antara kedua variabel eksogen dengan efektivitas pembelajaran. Model penelitian mampu menjelaskan 69,1 persen variansi kompetensi digital guru dan 73,4 persen variansi efektivitas pembelajaran, dengan tingkat kecocokan model yang baik (SRMR = 0,036). Temuan ini menegaskan bahwa penguatan kompetensi digital guru menjadi jalur penting yang menghubungkan dukungan kelembagaan dan ketersediaan sarana teknologi dengan kualitas pembelajaran di kelas..

Article History

Received : 28/07/2026

Revised : 12/08/2026

Accepted : 21/08/2026

✉ **Corresponding Author:** (1) Nono Suhada, (2) Universitas Bina Bangsa, Indonesia, (3) Email: nonosuhada14@gmail.com

1. Introduction

Digital transformation in education has become a major national education policy agenda, particularly since the implementation of the Merdeka Curriculum, which requires teachers to integrate technology into teaching and learning processes more adaptively. This policy is not merely an administrative recommendation but a consequence of the changing learning needs of students from the digital generation, who have grown up using internet-based devices and applications from an early age (Prensky, 2001). In this context, schools are expected to provide learning environments that support the effective use of technology, while teachers are expected to possess adequate teacher digital competence to use such technology meaningfully rather than merely as an administrative supplement.

The digital divide in Indonesia's education sector remains a tangible issue, particularly in areas outside major urban centers. Pandeglang Regency, one of the regions in Banten Province with diverse geographical characteristics, faces distinct challenges in the equitable distribution of educational technology infrastructure and the development of teacher digital competence. Although both central and local governments have allocated funds through School Operational Assistance (BOS) and the regional budget for the development of ICT facilities, implementation has not always been accompanied by tangible improvements in learning effectiveness. This phenomenon is consistent with the findings of Pettersson (2021), who stated that the availability of digital infrastructure in schools does not automatically lead to changes in instructional practices, as it continues to be influenced by school leadership, teacher work culture, and sustained institutional support.

Managerial support from school principals plays a strategic role in promoting the use of technology in the classroom. Leadership that can translate a school's digitalization vision into operational policies, ongoing training, and clear evaluation systems has been shown to foster a teacher work culture that is more open to change (Li, Cai, & Tang, 2023; Rosita & Iskandar, 2022). In addition, adequate ICT facility availability, including hardware, internet networks, and digital learning platforms, constitutes an essential technical prerequisite (Espinosa Andrade, Padilla, & Carrington, 2024). Nevertheless, managerial support and ICT facilities alone may not be sufficient to produce learning effectiveness if teachers, as the primary implementers of instruction, do not yet possess adequate teacher digital competence to operate and integrate these technologies into their pedagogical strategies (Guillén-Gámez, Ruiz-Palmero, & Gómez García, 2023).

Teacher digital competence, which encompasses technical, pedagogical, and ethical capabilities in using learning technologies, is frequently identified as a determining variable in the successful integration of technology into the classroom (Mishra & Koehler, 2006; Redecker & Punie, 2017). Several

previous studies have indicated that teacher digital competence can serve as a bridge linking institutional support and the availability of technological resources to student learning outcomes (Tzafilkou, Perifanou, & Economides, 2023; Peng, Abdul Razak, & Hajar Halili, 2023). Nevertheless, studies specifically examining the mediating role of teacher digital competence in the relationship among managerial support, ICT facilities, and learning effectiveness at State Senior High Schools (SMA Negeri) in regencies with semi-urban characteristics, such as Pandeglang, remain relatively limited. Most similar studies have been conducted in higher education contexts or in countries with substantially higher levels of digital maturity (García-Martínez, Rodríguez-Jiménez, & Yot-Domínguez, 2021); therefore, their generalizability to secondary school contexts in developing regions requires further empirical testing.

Based on the foregoing, this study aims to analyze the direct and indirect effects of managerial support and ICT facility availability on learning effectiveness through teacher digital competence as a mediating variable among teachers at State Senior High Schools (SMA Negeri) in Pandeglang Regency. The novelty of this study lies in its use of Structural Equation Modeling with Partial Least Squares (SEM-PLS) to simultaneously examine five direct-effect paths and two indirect-effect paths within an integrated model, thereby providing a more comprehensive understanding of the mechanisms through which institutional support and technological resources are translated into classroom learning quality. The findings of this study are expected to provide practical input for school principals and education policymakers in formulating more targeted and impactful strategies to strengthen teacher digital competence.

2. Literature Review and Hypothesis Development

This section outlines the conceptual foundations of the study's four variables—managerial support, ICT facility availability, teacher digital competence, and learning effectiveness—which subsequently serve as the basis for formulating the research hypotheses.

2.1 Managerial Support

Managerial support in the school context refers to the commitment and concrete actions of principals and management teams in providing policies, resources, training, and evaluation systems that encourage teachers to develop their teaching competence, including in the digital domain (Krantz, 2010). This concept is rooted in instructional leadership theory, which positions principals not only as administrators but also as facilitators of teachers' professional learning (Vanderlinde & van Braak, 2010). In their study of thousands of teachers in China, Li, Cai, and Tang (2023) found that school support and principals' instructional leadership contributed to teachers'

teaching expertise by strengthening their agency in professional development. Similar findings were reported by Rasdiana et al. (2024), who showed that digital-based instructional supervision and principals' technology leadership significantly improved teacher digital competence in Indonesian elementary and secondary schools.

In Indonesia, Rosita and Iskandar (2022) emphasized that principals' leadership styles adapted to the demands of the digital era constitute one of the determining factors in the successful transformation of learning in schools. Consistent managerial support, ranging from the provision of ICT integration policies and the allocation of training budgets to the delivery of constructive feedback, is believed to foster teachers' sense of psychological safety in trying new instructional methods and tools without fear of failure (Tuijl & Walraven, 2008).

2.2 ICT Facility Availability

ICT facilities encompass all hardware, software, internet connectivity, and digital platforms available in schools to support the teaching and learning process. The availability of these facilities is a technical prerequisite that enables teachers and students to use technology in everyday learning activities (Francom, 2020). A study by Espinosa Andrade, Padilla, and Carrington (2024), which analyzed the relationship between school infrastructure and learning outcomes, found that this relationship was positive but not always uniform, as the type and patterns of facility use were far more influential in determining their impact than mere physical availability. This finding indicates that investment in ICT facilities needs to be accompanied by targeted utilization strategies to genuinely affect classroom learning quality.

Consistent with this, Lim, Zhao, Tondeur, Chai, and Tsai (2013) identified limited infrastructure, insufficient training, and weak technical support as the primary barriers to ICT integration in schools in developing countries. Guillén-Gámez, Ruiz-Palmero, and Gómez García (2023) also emphasized that access to adequate ICT resources plays an important role in shaping teacher digital competence because the more frequently teachers are exposed to and use technological devices, the more skilled they become in using them pedagogically.

2.3 Teacher Digital Competence

Teacher digital competence is the integrated ability to combine technological, pedagogical, and subject-content knowledge, as conceptualized in the Technological Pedagogical Content Knowledge (TPACK) framework, to effectively design, implement, and evaluate digital learning (Mishra & Koehler, 2006). This framework was subsequently enriched by the European Framework for the Digital Competence of Educators (DigCompEdu), which specifies teacher digital competence

across several areas, ranging from professional engagement and the use of digital resources to digital pedagogy and learner empowerment (Redecker & Punie, 2017; Vuorikari, Kluzer, & Punie, 2022).

Various studies indicate that teacher digital competence is not merely the technical ability to operate applications but also encompasses the pedagogical capacity to design learning that meaningfully uses technology (Basilotta-Gómez-Pablos, Matarranz-Gómez, Casillas-Martín, & Céspedes-Rodríguez, 2022). Tzafilkou, Perifanou, and Economides (2023) developed an instrument to measure teacher digital competence that integrates pedagogical and professional elements and found that teachers with high digital competence tend to be better able to create interactive learning environments. Through a systematic literature review, Zhang, Yang, and Zheng (2026) also emphasized that mastery of digital competence enables teachers to guide students in using technology appropriately while laying the foundation for sustainable classroom learning quality.

In many research models, teacher digital competence is positioned as a mediating variable that links external supporting factors, such as school leadership and ICT facility availability, with learning outcomes (Peng, Abdul Razak, & Hajar Halili, 2023). This underscores that improving teacher digital competence is crucial for determining the extent to which the benefits of institutional support and technology investment can be realized directly in the classroom teaching and learning process.

2.4 Learning Effectiveness

Learning effectiveness is the degree to which instructional objectives are achieved across cognitive, affective, and psychomotor dimensions, and it is shaped through interactions among competent teachers, adequate facilities, institutional support, and instructional strategies that are responsive to students' needs (Albrecht & Karabenick, 2018). This effectiveness can be measured empirically through indicators such as learning mastery, students' active engagement, and improvements in conceptual understanding over time (Sorgo, 2021).

Several studies indicate that the appropriate use of technology in learning can increase students' participation and motivation to learn; however, its impact depends substantially on how teachers design and manage the learning process itself (Kulgemeyer, 2021). International assessment data also indicate that disparities in the use of educational technology across regions remain a tangible challenge to efforts to improve learning quality equitably (Schleicher, 2019). Therefore, learning effectiveness cannot be regarded as the result of a single factor but rather as the product of complex interactions among institutional support, ICT facility availability, and teachers' competence in making optimal use of these resources.

2.5 Conceptual Framework and Hypothesis Development

Based on the literature review above, this study develops a model that positions managerial support (X1) and ICT facility availability (X2) as exogenous variables that influence learning effectiveness (Z), both directly and through teacher digital competence (Y) as a mediating variable. This model reflects the assumption that institutional support and ICT facilities provide greater benefits for classroom learning quality when they first contribute to the development of teacher digital competence, as suggested by the findings of Rasdiana et al. (2024) and Peng, Abdul Razak, and Hajar Halili (2023).

Consistent managerial support, such as clear guidance and a willingness to listen to teachers' challenges, is believed to enhance teachers' confidence in managing classroom learning directly (Li, Cai, & Tang, 2023). Based on this rationale, the first hypothesis was formulated.

H1: Managerial support has a positive and significant effect on learning effectiveness.

Adequate ICT facility availability enables teachers to implement a wider variety of technology-based learning methods more flexibly, although the magnitude of this effect depends on usage patterns (Espinosa Andrade, Padilla, & Carrington, 2024). Based on this rationale, the second hypothesis was formulated.

H2: ICT facility availability has a positive and significant effect on learning effectiveness.

Managerial support in the form of training, mentoring, and constructive feedback is believed to be a key driver that encourages teachers to continuously develop their teacher digital competence (Rasdiana et al., 2024). Based on this rationale, the third hypothesis was formulated.

H3: Managerial support has a positive and significant effect on teacher digital competence.

Greater access to devices, networks, and learning applications provides teachers with more opportunities to practice and ultimately become more proficient in using technology (Guillén-Gámez, Ruiz-Palmero, & Gómez García, 2023). Based on this rationale, the fourth hypothesis was formulated.

H4: ICT facility availability has a positive and significant effect on teacher digital competence.

Teachers with high levels of teacher digital competence tend to be better able to design interactive learning that is relevant to students' needs, thereby contributing directly to learning effectiveness (Tzafilkou, Perifanou, & Economides, 2023). Based on this rationale, the fifth hypothesis was formulated.

H5: Teacher digital competence has a positive and significant effect on learning effectiveness.

Furthermore, based on findings that teacher digital competence

can serve as a bridge between institutional support and learning outcomes (Peng, Abdul Razak, & Hajar Halili, 2023), this study also examines the mediating role of teacher digital competence in the following two pathways.

H6: Teacher digital competence mediates the effect of managerial support on learning effectiveness.

H7: Teacher digital competence mediates the effect of ICT facility availability on learning effectiveness.

These seven hypotheses are illustrated in the research model in Figure 1, which presents five direct-effect pathways and two indirect-effect pathways tested simultaneously using the SEM-PLS approach.

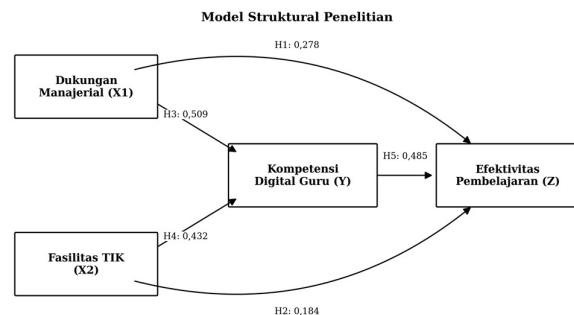


Figure 1. Research Model and Hypotheses

3. Research Methodology

This study employed a quantitative correlational design with a descriptive focus to measure and describe the relationships between managerial support (X1) and ICT facility availability (X2), on the one hand, and teacher digital competence (Y) and learning effectiveness (Z), on the other. A quantitative approach was selected because this study aimed to test the hypotheses objectively and measurably using numerical data collected from respondents through a structured questionnaire.

3.1 Research Location, Period, and Population

The study was conducted at five State Senior High Schools (SMA Negeri) in Pandeglang Regency, Banten Province—SMA Negeri 1, 2, 3, 4, and 5 Pandeglang—which were purposively selected because they represent public schools with A accreditation, the largest numbers of teachers and students in the regency, and sufficiently diverse conditions in terms of ICT facilities and managerial support. Data collection took place over four months, from February to May 2025, and included instrument development, pilot testing, questionnaire distribution, and data processing.

The study population comprised all 269 permanent teachers with Civil Servant (PNS) or Government Employee with Work Agreement (PPPK) status at the five schools. The sample size

was determined using the Slovin formula with a 5% margin of error, resulting in a minimum sample of 161 respondents. Sampling was conducted using proportionate stratified random sampling, ensuring that each school was represented proportionally according to its number of teachers, as presented in Table 1.

Table 1. Distribution of the Study Sample by School

School	Populati on	Sample
State Senior High School (SMA Negeri) 1 Pandeglang	58	35
State Senior High School (SMA Negeri) 2 Pandeglang	56	34
State Senior High School (SMA Negeri) 3 Pandeglang	62	37
State Senior High School (SMA Negeri) 4 Pandeglang	57	34
State Senior High School (SMA Negeri) 5 Pandeglang	36	21
Total	269	161

Source: Processed primary data, 2025

3.2 Instruments and Data Collection Techniques

Primary data were collected using a closed-ended five-point Likert-scale questionnaire ranging from 1 (strongly disagree) to 5 (strongly agree), developed based on an instrument blueprint for each variable. The managerial support variable was measured using 21 items covering the dimensions of ICT policy and planning, teacher competency training, program coordination, and monitoring and evaluation. The ICT facility availability variable was measured using 20 items covering the adequacy of physical infrastructure, network connectivity, and the availability of digital learning platforms. The teacher digital competence variable was measured using 23 items covering mastery of learning technologies, technology integration in pedagogy, and digital assessment and literacy. The learning effectiveness variable was measured using 21 items covering student competency attainment, active student engagement, and the quality of the learning process.

All instrument items underwent construct validity testing through expert review, empirical validity testing using Pearson product-moment correlation, and reliability testing using Cronbach's alpha, with a minimum criterion of 0.60. Secondary

data were obtained from official documents of the Pandeglang Regency Education Office, whereas tertiary data were obtained from relevant prior scientific publications for comparison and to strengthen the theoretical framework.

3.3 Data Analysis Techniques

The data were analyzed in two main stages: descriptive statistical analysis and inferential analysis using Structural Equation Modeling with Partial Least Squares (SEM-PLS). Descriptive analysis was used to describe data characteristics through the minimum, maximum, mean, median, mode, and standard deviation values for each variable.

SEM-PLS analysis was selected because of its ability to simultaneously test complex structural models with mediating variables without requiring strict assumptions of normal data distribution (Hair, Hult, Ringle, & Sarstedt, 2017). Model evaluation was conducted in two stages. First, the measurement model (outer model) was evaluated through construct reliability testing using composite reliability and Cronbach's alpha, with a minimum threshold of 0.70; convergent validity testing using average variance extracted (AVE), with a minimum threshold of 0.50; and discriminant validity testing using the heterotrait-monotrait (HTMT) ratio, with a maximum threshold of 0.85. Second, the structural model (inner model) was evaluated through path significance testing using bootstrap resampling of 5,000 iterations, coefficient of determination (R-squared) testing, effect size (f-squared) testing, mediation effect testing using 95% confidence intervals, and model fit testing using the Standardized Root Mean Square Residual (SRMR), with a maximum threshold of 0.08.

Hypothesis testing was conducted at a 5% significance level, with the alternative hypothesis accepted if the t-statistic was greater than or equal to 1.96 or the p-value was less than 0.05.

4. Results and Discussion

4.1 Description of Study Data

Study data were collected from 161 permanent teachers at five State Senior High Schools (SMA Negeri) in Pandeglang Regency. The results of the descriptive statistical analysis for the four study variables are presented in Table 2.

Table 2. Descriptive Statistics of Study Variables (N = 161)

Variable	Mini mu m Scor e	Maxi mum Score	Mea n	Median	Std. Deviati on
Managerial Support (X1)	21.5	103.0	63.89	64.00	18.14

Variable	Minimum Score	Maximum Score	Mean	Median	Std. Deviation
ICT Facilities (X2)	20.5	96.0	60.05	61.00	16.45
Teacher Digital Competence (Y)	25.0	114.0	69.99	70.00	22.65
Learning Effectiveness (Z)	25.5	100.0	63.23	61.50	19.33

Source: Primary data analyzed using SEM-PLS, 2025

The mean empirical scores for all four variables fell within the moderate to upper-moderate categories of their respective theoretical scales. Teacher digital competence had the highest standard deviation (22.65), indicating substantial variation in teachers' digital abilities, whereas ICT facilities had the lowest standard deviation (16.45), indicating that teachers' perceptions of technology resource availability were relatively more homogeneous than their perceptions of the other variables.

4.2 Measurement Model Evaluation (Outer Model)

Before testing the relationships among variables, the quality of the measurement model was evaluated to ensure that each construct was measured validly and reliably. The results of the reliability and convergent validity tests are presented in Table 3.

Table 3. Construct Reliability and Convergent Validity

Construct	Cronbach's Alpha	Composite Reliability	AVE
Managerial Support	0.984	0.985	0.764
ICT Facilities	0.983	0.984	0.755
Teacher Digital Competence	0.984	0.985	0.738
Learning Effectiveness	0.986	0.987	0.788

Source: SmartPLS data analysis results, 2025

All constructs demonstrated Cronbach's alpha and composite reliability values above 0.70, as well as AVE values above 0.50, indicating that the four constructs in this study had good reliability and convergent validity. The outer loading analysis also showed that all indicators had values above 0.60, with most exceeding 0.70, indicating that each survey item validly

measured its intended construct. Several indicators with the highest loadings included the item concerning the principal's vision for digital transformation in the managerial support construct, the item concerning the availability of computer laboratories in the ICT facilities construct, the item concerning the ability to operate a learning management system in the teacher digital competence construct, and the item concerning students' achievement of learning targets in the learning effectiveness construct.

Discriminant validity testing using the Heterotrait-Monotrait (HTMT) ratio showed that all values were below the conservative threshold of 0.85, with the highest value (0.836) observed between the teacher digital competence and learning effectiveness constructs. These results indicate that each construct in the research model had sufficiently distinct characteristics and did not overlap with the others.

4.3 Structural Model (Inner Model) Evaluation and Hypothesis Testing

After the measurement model was deemed valid and reliable, the next stage was to test the structural model to determine the significance of the relationships among variables. Testing was conducted using bootstrap resampling of 5,000 iterations, and the results are presented in Table 4.

Table 4. Direct-Effect Path Testing Results

Path	Coefficient	t Statistic	p Value	Description
Managerial Support -> Learning Effectiveness	0.278	4.870	0.000	Significant
ICT Facilities -> Learning Effectiveness	0.184	2.964	0.003	Significant
Managerial Support -> Teacher Digital Competence	0.509	10.387	0.000	Significant
ICT Facilities -> Teacher Digital Competence	0.432	8.775	0.000	Significant

Path	Coefficient	t Statistic	p Value	Description
Teacher Digital Competence -> Learning Effectiveness	0.485	7.171	0.000	Significant

Source: SmartPLS data analysis results, 2025

Table 5. Mediation Effects of Teacher Digital Competence

Indirect Path	Coefficient	t Statistic	p Value	Description
Managerial Support -> Teacher Digital Competence -> Learning Effectiveness	0.247	5.995	0.000	Significant Mediation
ICT Facilities -> Teacher Digital Competence -> Learning Effectiveness	0.210	5.266	0.000	Significant Mediation

Source: SmartPLS data analysis results, 2025

The results in Table 4 show that all five direct-effect paths were significant at the 0.05 level, with all t-statistic values exceeding the threshold of 1.96. Meanwhile, Table 5 shows that teacher digital competence significantly mediated the effects of both managerial support and ICT facilities on learning effectiveness because the confidence intervals for the indirect effects in both paths did not include zero.

The coefficients of determination (R square) indicated that the research model explained 69.1% of the variance in teacher digital competence and 73.4% of the variance in learning effectiveness, both of which fall within the large-effect category according to the criteria of Hair et al. (2017). The model fit test using the Standardized Root Mean Square Residual (SRMR) yielded a value of 0.036, well below the threshold of 0.08, indicating that the structural model had an excellent fit with the empirical data.

4.4 Discussion

4.4.1 The Effect of Managerial Support on Learning Effectiveness

The test results showed that managerial support had a positive and significant effect on learning effectiveness (coefficient = 0.278; $t = 4.870$; $p = 0.000$); therefore, H1 was accepted. This finding means that the better the support teachers perceived from school principals, the more effective the learning they implemented in the classroom. Such support does not necessarily have to involve major initiatives. Clear guidance, school principals' willingness to listen to teachers' challenges, and encouragement to try new teaching methods were sufficient to make teachers feel more confident and consistent in managing learning.

This finding is consistent with Li, Cai, and Tang (2023), who found that school principals' instructional leadership support also shaped teachers' teaching expertise, although the magnitude of its contribution varied depending on the extent to which teachers experienced the support in practice. Rosita and Iskandar (2022) also emphasized that school principal leadership styles capable of adapting to the demands of the digital era constitute an important factor in promoting the quality of learning processes in schools.

4.4.2 The Effect of ICT Facilities on Learning Effectiveness

ICT facility availability was also found to have a positive and significant effect on learning effectiveness (coefficient = 0.184; $t = 2.964$; $p = 0.003$); therefore, H2 was accepted. Although significant, this path coefficient was the smallest among the five direct-effect paths tested. This finding is reasonable because the mere availability of devices or internet networks does not necessarily make learning more effective. These facilities become beneficial only when teachers use them appropriately in the teaching process.

This finding reinforces the results of Espinosa Andrade, Padilla, and Carrington (2024), which showed that the relationship between school infrastructure and learning achievement was positive but not always uniform because the type and utilization of facilities were more decisive in determining their impact than their mere physical availability. In other words, investment in ICT facilities in schools needs to be accompanied by clear utilization strategies so that its impact on learning effectiveness can be optimized.

4.4.3 The Effect of Managerial Support on Teacher Digital Competence

Managerial support had a positive and significant effect on teacher digital competence (coefficient = 0.509; $t = 10.387$; $p = 0.000$); therefore, H3 was accepted. This coefficient was the largest among all direct-effect paths in this study, indicating that

support from school principals was the strongest driver of improvements in teacher digital competence compared with the other exogenous variables. When school principals actively provided training opportunities, supported the process of technology adaptation, and offered constructive feedback, teachers became more open to continuously developing their digital capabilities.

These results are consistent with the findings of Rasdiana et al. (2024), which showed that school principals' instructional supervision and technology leadership made a meaningful contribution to improving teacher digital competence. Li, Cai, and Tang (2023) also emphasized that institutional support from school leaders is an important prerequisite for the development of teachers' professional expertise, including in the digital domain.

4.4.4 The Effect of ICT Facilities on Teacher Digital Competence

ICT facility availability had a positive and significant effect on teacher digital competence (coefficient = 0.432; $t = 8.775$; $p = 0.000$); therefore, H4 was accepted. Teachers with better access to devices, networks, and learning applications tended to have more opportunities to practice and consequently became more proficient in using technology in their daily work.

This finding is consistent with Guillén-Gámez, Ruiz-Palmero, and Gómez García (2023), who showed that access to and use of ICT resources play an important role in shaping teacher digital competence. Peng, Abdul Razak, and Hajar Halili (2023) also found that facilities and infrastructure are among the determinants of teachers' success in integrating technology into learning.

4.4.5 The Effect of Teacher Digital Competence on Learning Effectiveness

Teacher digital competence had a positive and significant effect on learning effectiveness (coefficient = 0.485; $t = 7.171$; $p = 0.000$); therefore, H5 was accepted. This coefficient was the largest among the three paths leading to learning effectiveness, indicating that teacher digital competence was the most decisive factor for classroom learning quality compared with the direct effects of managerial support and ICT facilities.

These results reinforce Tzafilkou, Perifanou, and Economides's (2023) view that teacher digital competence is essential for the effective implementation of technology in school learning. Zhang, Yang, and Zheng (2026) also emphasized that mastery of digital competence enables teachers to guide students in using technology appropriately while laying the foundation for improved classroom learning quality.

4.4.6 The Mediating Role of Teacher Digital Competence in the Relationship Between Managerial Support and Learning Effectiveness

The mediation test results showed that teacher digital competence significantly mediated the effect of managerial support on learning effectiveness (indirect effect = 0.247; $t = 5.995$; $p = 0.000$); therefore, H6 was accepted. Because the direct effect of managerial support on learning effectiveness also remained significant, this mediation effect was classified as partial mediation. The indirect effect, which was nearly equivalent to the direct effect, indicates that improving teacher digital competence is one of the primary pathways through which principal support can enhance learning effectiveness, rather than merely functioning as administrative encouragement. A similar mediation pattern was identified in the study by Rasdiana et al. (2024), which showed that the effect of principal leadership on teachers' professional digital competence was greater when examined through school digital culture as a mediating variable than when examined through the direct effect alone. This finding reinforces the argument that school leadership support has a more optimal impact on classroom learning quality when it is explicitly directed toward first developing teacher digital competence.

4.4.7 The Mediating Role of Teacher Digital Competence in the Relationship Between ICT Facilities and Learning Effectiveness

Teacher digital competence also significantly mediated the effect of ICT facilities on learning effectiveness (indirect effect = 0.210; $t = 5.266$; $p = 0.000$); therefore, H7 was accepted. Notably, this indirect effect was greater than the direct effect of ICT facilities on learning effectiveness (coefficient = 0.184). This pattern indicates that the benefits of ICT facilities for learning effectiveness are realized more substantially through improvements in teacher digital competence than through the direct effect of merely providing devices and networks.

This finding is consistent with Peng, Abdul Razak, and Hajar Halili (2023), who emphasized that digital competence plays a mediating role in explaining how supporting factors, including facilities, affect teachers' success in technology integration. Accordingly, policies for procuring ICT facilities in schools have a greater impact when accompanied by programs to strengthen teacher digital competence, rather than being limited to the provision of devices.

Overall, all seven hypotheses in this study were supported by the data. Managerial support and ICT facilities both played important roles in improving learning effectiveness, both directly and through improvements in teacher digital competence. However, managerial support appeared to play a more dominant role in shaping teacher digital competence, whereas the role of ICT facilities was more pronounced when mediated through improvements in teacher digital competence. These findings confirm that teacher digital competence occupies a central position in linking institutional support and the availability of technological resources to classroom learning quality.

5. Conclusion

5.1 Conclusion

This study concludes that managerial support and ICT facility availability each had a positive and significant effect on learning effectiveness, both directly and indirectly through teacher digital competence as a mediating variable. Managerial support was shown to be the strongest driver of improvements in teacher digital competence, whereas teacher digital competence itself was the most decisive factor in learning effectiveness compared with the direct effects of the two exogenous variables. The mediating role of teacher digital competence was significant in both tested pathways, with a partial mediation pattern in the managerial support pathway and an indirect effect that was even stronger than the direct effect in the ICT facilities pathway. Thus, strengthening teacher digital competence is the key mechanism linking institutional support and the availability of technological resources to classroom learning quality.

5.2 Study Limitations

This study has several limitations that should be considered when interpreting its findings. First, the study used a cross-sectional design; therefore, data were collected at a single point in time, and the relationships identified among the variables were correlational and cannot fully demonstrate long-term causal relationships. Second, data were collected through a self-report questionnaire; consequently, respondents' answers may have been influenced by subjective perceptions or a tendency to provide socially desirable responses.

Third, the study sample was limited to 161 permanent teachers from five State Senior High Schools (SMA Negeri) in Pandeglang Regency; therefore, the findings may not be generalizable to teachers at other educational levels, private schools, or regions with different social and geographic characteristics. Fourth, the research model included only two exogenous variables and one mediating variable; thus, other factors that may theoretically influence learning effectiveness, such as teacher work motivation, teaching experience, or school culture, were not included in the model.

5.3 Recommendations

Based on these findings and limitations, school principals in Pandeglang Regency are advised to design structured and sustainable programs to strengthen teacher digital competence rather than limiting their efforts to providing ICT facilities alone. The local Education Office is also advised to integrate indicators of teacher digital competence into school development and performance evaluation systems. Future researchers are advised to expand the sample to other educational levels, include additional variables such as work motivation or school culture, and use longitudinal research designs to strengthen evidence of causal relationships among variables.

Acknowledgments

The authors thank the Pandeglang Regency Education Office, as well as the principals and teachers from the five State Senior

High Schools (SMA Negeri) who participated in this study. The authors also express their appreciation to their academic advisors for their guidance and feedback throughout the research process. This study received no specific funding from any party.

References

- Albrecht, N. J., & Karabenick, S. A. (2018). Relevance for learning and motivation in education. *The Journal of Experimental Education*, 86(3), 455-472. <https://doi.org/10.1080/00220973.2017.1380590>
- Basilotta-Gómez-Pablos, V., Matarranz-Gómez, A., Casillas-Martin, S., & Céresoles-Rodríguez, J. D. (2022). Teachers' digital competencies on online teaching: A systematic literature review. *Education Sciences*, 12(8), 497. <https://doi.org/10.3390/educsci12080497>
- Cabero-Almenara, J., Guillén-Gámez, F. D., Ruiz-Palmero, J., & Palacios-Rodríguez, A. (2020). Digital technology acceptance by university teachers: A priority study in COVID-19 times. *Education Sciences*, 11(1), 6. <https://doi.org/10.3390/educsci11010006>
- Cai, Y., & Tang, R. (2021). School support for teacher innovation: Mediating effects of teacher self-efficacy and moderating effects of trust. *Thinking Skills and Creativity*, 41, 100854. <https://doi.org/10.1016/j.tsc.2021.100854>
- Carretero, S., Vuorikari, R., & Punie, Y. (2017). DigComp 2.1: The digital competence framework for citizens with eight proficiency levels and examples of use. Publications Office of the European Union. <https://doi.org/10.2760/38842>
- Espinosa Andrade, A., Padilla, L., & Carrington, S. J. (2024). Educational spaces: The relation between school infrastructure and learning outcomes. *Heliyon*, 10(19), e38361. <https://doi.org/10.1016/j.heliyon.2024.e38361>
- Francom, G. M. (2020). Barriers to technology integration in a classroom setting. *The Journal of Instructional Research*, 9, 44-57.
- García-Martínez, J., Rodríguez-Jiménez, R., & Yot-Domínguez, C. (2021). Teachers' digital competencies and distance learning during COVID-19 pandemic: A literature review. *Education Sciences*, 11(12), 769. <https://doi.org/10.3390/educsci11120769>
- Guillén-Gámez, F. D., Ruiz-Palmero, J., & Gómez García, M. (2023). Digital competence of teachers in the use of ICT for research work: Development of an instrument from a PLS-SEM approach. *Education and Information Technologies*, 28, 13011-13030. <https://doi.org/10.1007/s10639-023-11895-2>
- Hair, J. F., Hult, G. T. M., Ringle, C. M., & Sarstedt, M. (2017). A primer on partial least squares structural equation modeling (PLS-SEM) (2nd ed.). SAGE Publications.
- Kampylis, P., Punie, Y., & Devine, J. (2015). Promoting effective digital-age learning: A European framework for digitally competent educational organisations. Publications

- Office of the European Union.
- Krantz, J. (2010). Assessing school technology leadership. *International Journal of Educational Leadership Preparation*, 5(6), 1-11.
- König, J., Jäger-Biela, D. J., & Glutsch, N. (2020). Adapting to online teaching during COVID-19 school closure: teacher education and teacher competence effects at secondary schools in Germany. *European Journal of Teacher Education*, 43(4), 608-622. <https://doi.org/10.1080/02619768.2020.1809650>
- Kulgemeyer, C. (2021). Student talk about digital media in physics lessons: Insights from students' perspective. *Education Sciences*, 11(6), 297. <https://doi.org/10.3390/educsci11060297>
- Li, Y., Cai, Y., & Tang, R. (2023). Linking instructional leadership and school support to teacher expertise: The mediating effect of teachers' professional development agency. *Sustainability*, 15(4), 3440. <https://doi.org/10.3390/su15043440>
- Lim, C. P., Zhao, Y., Tondeur, J., Chai, C. S., & Tsai, C. C. (2013). Exploring the main obstacles to the integration of ICT into teaching in Chinese schools: An exploratory study. *Educational Technology Research and Development*, 61(3), 433-450. <https://doi.org/10.1007/s11423-013-9298-1>
- Mishra, P., & Koehler, M. J. (2006). Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6), 1017-1054. <https://doi.org/10.1111/j.1467-9620.2006.00684.x>
- Peng, R., Abdul Razak, R., & Hajar Halili, S. (2023). Factors influencing in-service teachers' technology integration model: Innovative strategies for educational technology. *PLOS ONE*, 18(8), e0286112. <https://doi.org/10.1371/journal.pone.0286112>
- Pettersson, F. (2021). Understanding digitalization and educational change in school by means of activity theory and the levels of learning concept. *Education and Information Technologies*, 26(1), 187-204. <https://doi.org/10.1007/s10639-020-10239-8>
- Prensky, M. (2001). Digital natives, digital immigrants. *On the Horizon*, 9(5), 1-6. <https://doi.org/10.1108/10748120110424843>
- Purnomo, E. N., Imron, A., Wiyono, B. B., Sobri, A. Y., & Dami, Z. A. (2024). Transformation of digital-based school culture: Implications of change management on virtual learning environment integration. *Cogent Education*, 11(1), 2303562. <https://doi.org/10.1080/2331186X.2024.2303562>
- Rasdiana, Wiyono, B. B., Imron, A., Rahma, L., Arifah, N., Azhari, R., Elfira, & Maharmawan, M. A. (2024). Elevating teachers' professional digital competence: Synergies of principals' instructional e-supervision, technology leadership and digital culture for educational excellence in digital-savvy era. *Education Sciences*, 14(3), 266. <https://doi.org/10.3390/educsci14030266>
- Redecker, C., & Punie, Y. (2017). European framework for the digital competence of educators: DigCompEdu. Publications Office of the European Union. <https://doi.org/10.2760/159770>
- Rosita, R., & Iskandar, S. (2022). Gaya kepemimpinan kepala sekolah di era digital. *Jurnal Basicedu*, 6(4), 6005-6011. <https://doi.org/10.31004/basicedu.v6i4.3127>
- Schleicher, A. (2019). PISA 2018: Insights and interpretations. Organisation for Economic Co-operation and Development.
- Siddiq, F., Gochyyev, P., & Wilson, M. (2017). Learning in digital networks: ICT literacy: A novel assessment of students' 21st century skills. *Computers & Education*, 109, 11-37. <https://doi.org/10.1016/j.compedu.2017.02.005>
- Sorgo, A. (2021). Improvement of student learning outcomes at secondary level by technology-enhanced inquiry-based learning: The quantified student outcome. *Education Sciences*, 11(6), 308. <https://doi.org/10.3390/educsci11060308>
- Tondeur, J., van Braak, J., Ertmer, P. A., & Ottenbreit-Leftwich, A. (2017). Understanding the relationship between teachers' pedagogical beliefs and technology use in education: A systematic review of qualitative evidence. *Educational Technology Research and Development*, 65(3), 555-575. <https://doi.org/10.1007/s11423-016-9481-2>
- Tuijl, H., & Walraven, A. (2008). Student participation in teacher professionalism: Implementing sustainable institutional change. *Teaching and Teacher Education*, 24(8), 2087-2103. <https://doi.org/10.1016/j.tate.2008.03.010>
- Tzaflikou, K., Perifanou, M., & Economides, A. A. (2023). Assessing teachers' digital competence in primary and secondary education: Applying a new instrument to integrate pedagogical and professional elements for digital education. *Education and Information Technologies*, 28, 16017-16040. <https://doi.org/10.1007/s10639-023-11848-9>
- Vanderlinde, R., & van Braak, J. (2010). School-based ICT policy plans in primary education: Elements, typologies and underlying processes. *British Journal of Educational Technology*, 41(3), 451-470. <https://doi.org/10.1111/j.1467-8535.2009.00951.x>
- Vuorikari, R., Kluzer, S., & Punie, Y. (2022). DigComp 2.2: The digital competence framework for citizens with new examples of knowledge, skills and attitudes. Publications Office of the European Union. <https://doi.org/10.2760/115376>
- Zhang, L., Yang, C., & Zheng, Y. (2026). Digital competence for sustainable education of pre-service teachers: A systematic literature review (2014-2024). *Frontiers in Psychology*, 16, 1710983. <https://doi.org/10.3389/fpsyg.2025.17109>