Indonesian Journal of Applied and Industrial Sciences (ESA)
Vol. 5, No. 1, 2026 : 15 - 28

# The Influence of Teacher's Knowledge of Educational Technology and Infrastructure on Learning Quality Through the Digital Competence of State Elementary School Teachers in Motaain

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A R T I C L E I N F O

*Keywords:* Knowledge of Educational Technology, Facilities and Infrastructure, Digital Competence, Learning Quality

*Received : 20 November 2025*
*Revised : 21 December 2025*
*Accepted: 25 January 2026*



A B S T R A C T

This study examines the effect of teachers' educational technology knowledge and school infrastructure on learning quality, mediated by digital competence, in Motaain's public elementary schools. Using a quantitative approach, data from 168 teacher respondents were analyzed via PLS-SEM with SmartPLS. Results show that both technology knowledge (β=0.301, p<0.001) and infrastructure (β=0.284, p<0.001) significantly enhance digital competence, which in turn positively impacts learning quality (β=0.412, p<0.001) and fully mediates the relationship. The findings highlight that digital competence is the strongest predictor of learning quality, underscoring the need for targeted development of teacher digital skills, supported by adequate knowledge and facilities, especially in border region schools.

DOI: https://doi.org/10.55927/esa.v5i1.204
E-ISSN : 2985-5055
https://esaformosapublisher.org/index.php/esa

## INTRODUCTION

The rapid digital transformation of education has reshaped how teaching and learning are organized, delivered, and evaluated. Technology is no longer a supplementary tool but an integral component of effective pedagogy that enhances interaction, engagement, and learning outcomes (Reiser, 2001). In this context, teachers are expected to move beyond traditional instructional roles and function as facilitators who integrate digital resources into student-centered learning environments (Akrim, 2018; Sharma, 2018). The Technological Pedagogical Content Knowledge (TPACK) framework emphasizes that effective instruction depends on the integration of technological, pedagogical, and content knowledge (Mishra & Koehler, 2006), highlighting the importance of teachers' knowledge of educational technology in improving instructional quality.

However, teachers' technological knowledge alone is insufficient without adequate institutional support. The availability of facilities and infrastructure such as computers, internet access, multimedia tools, and conducive classrooms plays a critical role in enabling the implementation of digital learning practices (Bafadal, 2008; Hanafi, 2015). Schools with limited or poorly maintained resources often struggle to adopt innovative teaching strategies, which ultimately affects learning effectiveness (Anwar & Wahyudi, 2019; Lestari, 2023). Thus, both individual competence and environmental readiness are essential determinants of learning quality.

Teachers' digital competence has consequently emerged as a key factor linking technology use and learning outcomes. Digital competence refers to the ability to utilize digital tools strategically, ethically, and pedagogically to design, manage, and evaluate learning processes (Ferrari et al., 2012; Hunaidah et al., 2023). Teachers with strong digital competence are better able to create interactive materials, manage digital classrooms, and improve student engagement (Ma'rifah et al., 2021; Oktarizka, 2022). Although previous studies confirm its positive influence on instructional effectiveness, most examine digital competence as a direct predictor, while its mediating role between technological knowledge, infrastructure, and learning quality remains underexplored.

Addressing this gap, the present study investigates elementary schools located in the Indonesia–Timor Leste border area, a context characterized by limited infrastructure, low digital literacy, and restricted professional development opportunities. By examining teachers' knowledge of educational technology and school facilities as antecedents of digital competence and testing digital competence as a mediator of learning quality, this study offers a more comprehensive explanatory model that integrates individual and organizational factors. This research therefore contributes empirical evidence from an underrepresented setting while enriching theoretical discussions on how digital competence functions as a mechanism for improving learning quality in disadvantaged schools.

## LITERATURE REVIEW

### 1. Technological Pedagogical Content Knowledge (TPACK) Theory

The Technological Pedagogical Content Knowledge (TPACK) theory explains that effective teaching emerges from the integration of three domains of knowledge: content, pedagogy, and technology (Mishra & Koehler, 2006). Teachers are not only required to master subject matter and instructional strategies but also to understand how technology can meaningfully support learning activities. This integrated knowledge enables educators to design interactive instruction, select appropriate digital tools, and adapt teaching approaches to diverse learning needs. Therefore, teachers' knowledge of educational technology forms the cognitive foundation for developing practical digital skills in the classroom.

Supriandi et al. (2024) and Haza and Abdurrahmansyah (2025) found that teachers with higher technological knowledge demonstrate stronger digital competence and greater effectiveness in technology-based instruction. Similarly, Shofia and Ahsani (2021) reported that mastery of information technology significantly improves instructional quality. These findings suggest that knowledge of educational technology positively contributes to teachers' digital competence and learning quality. Based on this theoretical and empirical evidence, this study proposes that teachers' knowledge of educational technology positively influences digital competence and, directly and indirectly, enhances learning quality.

### 2. Educational Facilities and Infrastructure Theory

Educational facilities and infrastructure theory emphasizes that physical and technological resources are critical enablers of effective educational processes. Facilities such as classrooms, laboratories, computers, and internet access directly support teaching activities, while infrastructure provides indirect environmental support that ensures learning continuity (Bafadal, 2008; Hanafi, 2015). Adequate infrastructure creates opportunities for teachers to apply innovative and technology-supported strategies, whereas insufficient resources restrict experimentation and limit instructional effectiveness.

Anwar and Wahyudi (2019) and Lestari (2023) demonstrated that adequate facilities significantly improve teacher performance and student engagement. Ngongo and Talok (2023) further showed that digital learning facilities positively affect teachers' digital competence and professional outcomes. Conversely, schools with limited infrastructure experience difficulties in integrating technology into daily instruction. These studies support the assumption that facilities and infrastructure positively influence both teachers' digital competence and learning quality, forming the basis for the hypotheses related to environmental support factors in this study.

### 3. Digital Competence Theory

Digital competence theory conceptualizes teachers' ability to use digital technology effectively, critically, and ethically in instructional contexts (Ferrari et al., 2012). Digital competence includes selecting appropriate tools, managing digital classrooms, creating multimedia materials, and facilitating online

collaboration. Rather than focusing solely on technical skills, this theory highlights pedagogical application, where technology becomes a means to enhance interaction, motivation, and learning outcomes (Hunaidah et al., 2023). Teachers with higher digital competence are therefore more capable of delivering adaptive and engaging instruction.

Ma'rifah et al. (2021) and Oktarizka (2022) found that teachers' digital competence significantly improves instructional management and classroom effectiveness. Hibana and Surahman (2021) reported that digital competence contributes directly to educational achievement, while Rasdiana and Maharmawan (2024) emphasized its importance in enhancing professional teaching performance. These findings suggest that digital competence functions as a critical predictor of learning quality and may serve as an explanatory mechanism linking technological knowledge and infrastructure to instructional improvement. Hence, this study positions digital competence as both a direct determinant and a mediating variable affecting learning quality.

**4. Learning Quality Theory**

Learning quality theory defines high-quality learning as the effective organization, delivery, and management of instruction that leads to meaningful student understanding and skill development (Uno, 2021; Bamiro, 2023). Quality learning involves structured planning, diverse teaching methods, appropriate media use, and continuous feedback. Technology integration and teacher competence are increasingly recognized as essential components of this process, particularly in modern digital classrooms where interaction and accessibility determine student engagement.

Dewi (2024) and Sadriani (2023) reported that technology utilization improves instructional effectiveness, while Dwiputri and Febriyanti (2021) showed that proper facility management enhances online and blended learning outcomes. However, most of these studies examine direct relationships and rarely explore how digital competence mediates the effects of technological knowledge and infrastructure on learning quality. Addressing this gap, the present study proposes an integrated model in which teachers' knowledge of educational technology and school facilities influence learning quality both directly and indirectly through the mediating role of teachers' digital competence.

**H1**. Teachers' knowledge of educational technology positively influences teachers' digital competence.
**H2**. Teachers' knowledge of educational technology positively influences learning quality.
**H3**. School facilities and infrastructure positively influence teachers' digital competence.
**H4**. School facilities and infrastructure positively influence learning quality.
**H5**. Teachers' digital competence positively influences learning quality.
**H6**. Teachers' digital competence mediates the relationship between teachers' knowledge of educational technology and learning quality.
**H7**. Teachers' digital competence mediates the relationship between school facilities and infrastructure and learning quality.

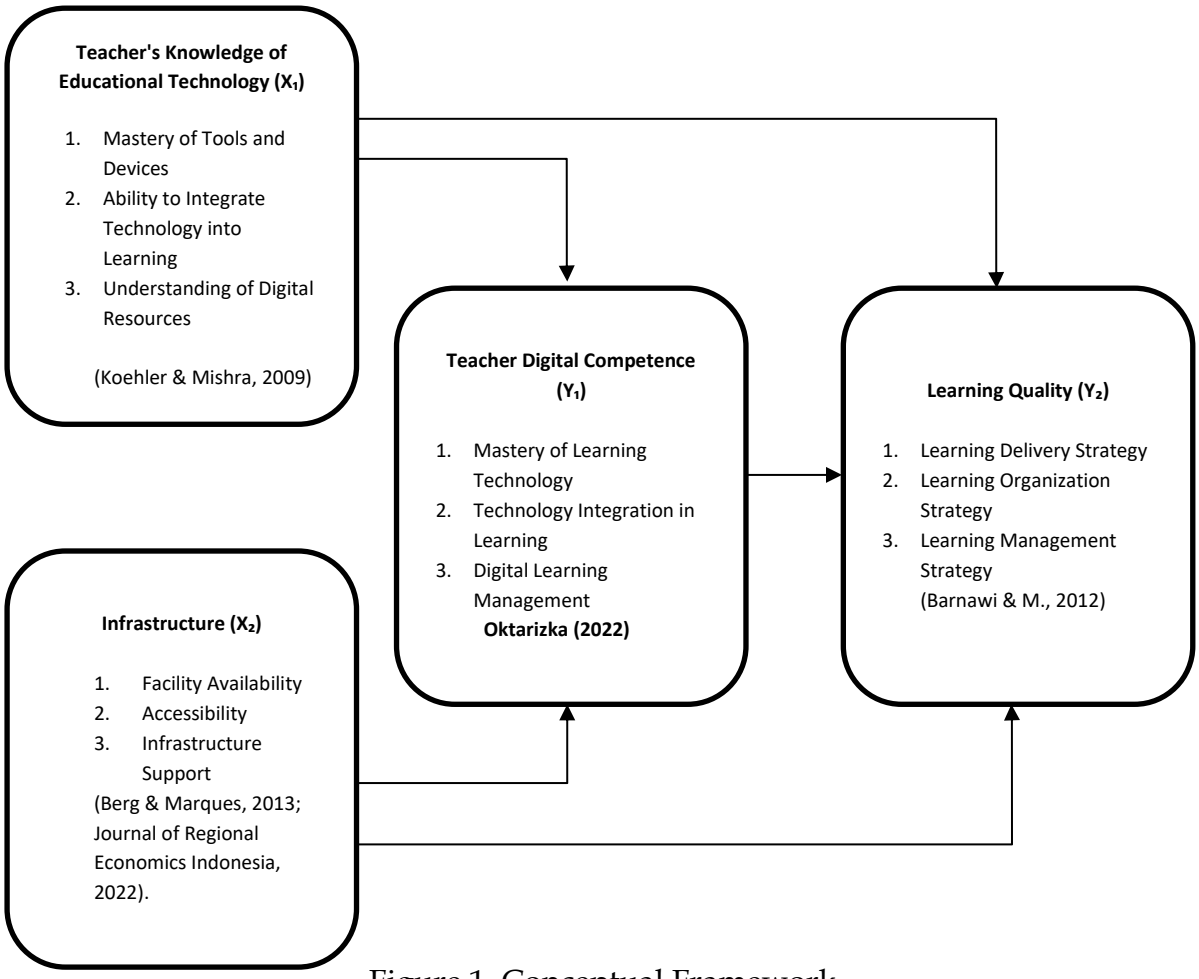


Figure 1. Conceptual Framework

## METHODOLOGY

This study employed a quantitative, explanatory design using a cross-sectional survey to examine the relationships among teachers' knowledge of educational technology, school facilities and infrastructure, teachers' digital competence, and learning quality. The approach was selected to test causal relationships and mediation effects within a theory-driven structural model. The research was conducted in public elementary schools located in the Indonesia–Timor Leste border area, a disadvantaged and underrepresented context characterized by limited digital resources and professional development opportunities, providing a unique setting for investigating technology integration in education.

The population comprised all teachers working in these border schools. A saturated sampling technique was applied, inviting all accessible teachers to participate, resulting in 168 valid responses used as the final sample. Data were collected through a structured questionnaire with multi-item constructs adapted from established literature. The instrument measured teachers' knowledge of educational technology, school facilities and infrastructure, teachers' digital competence, and learning quality using a five-point Likert scale ranging from strongly disagree to strongly agree to ensure standardized responses and reliable measurement.

Data analysis was conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS software, as this method is suitable for predictive models, medium sample sizes, and mediation testing. The analysis consisted of two stages: evaluation of the measurement model to assess reliability and validity, followed by assessment of the structural model to examine path coefficients, coefficients of determination, and hypothesis significance through bootstrapping. Indirect effect analysis was performed to determine the mediating role of teachers' digital competence in explaining the influence of technological knowledge and infrastructure on learning quality.

## RESEARCH RESULT

The data analysis was conducted using Partial Least Squares Structural Equation Modeling (PLS-SEM) with SmartPLS software to evaluate both the measurement model and the structural relationships among constructs. The procedure followed two main stages: assessment of the outer model to ensure reliability and validity of the instruments, and evaluation of the inner model to test the proposed hypotheses and mediation effects.

### 1. Measurement Model Evaluation (Outer Model)

The measurement model was first assessed by examining indicator reliability, internal consistency reliability, convergent validity, and discriminant validity.

Table 1 Outer Loading, Cronbach's Alpha, Composite Reliability and Average Variance Extracted

| Variabel | Indicator | *Loading factor* | *Cronbach's Alpha* | *Composite Reliabilty* | AVE |
|---|---|---|---|---|---|
| **X1 - Teacher's Knowledge** | **PG1 PAP** | 0,942 | 0,941 | 0,962 | 0,895 |
| | **PG2 PSDD** | 0,942 | | | |
| | **PG3 KMT** | 0,953 | | | |
| **X2 - Infrastructure** | **SP1 KS** | 0,960 | 0,950 | 0,967 | 0,908 |
| | **SP2 A** | 0,947 | | | |
| | **SP3 DI** | 0,952 | | | |
| **Y1 - Teacher Digital Competence** | **KDG1 PTP** | 0,964 | 0,967 | 0,978 | 0,938 |
| | **KDG2 IT** | 0,977 | | | |
| | **KDG3 PPD** | 0,964 | | | |
| **Y2 - Learning Quality** | **KP1** | 0,953 | 0,949 | 0,967 | 0,908 |
| | **KP2** | 0,961 | | | |
| | **KP3** | 0,944 | | | |

Table 1 presents the results of the measurement model assessment, which evaluates the convergent validity and internal consistency reliability of the four reflective constructs in this study. This assessment is a critical prerequisite for

validating the measurement scales before proceeding to structural model analysis. The evaluation focuses on three key metrics for each construct: the individual indicator loadings, composite reliability (CR), and average variance extracted (AVE). Cronbach's Alpha is also reported as an additional measure of internal consistency.

The results for the exogenous variables indicate a robust measurement structure. For Teacher's Knowledge (X1), all three indicator loadings are exceptionally high, ranging from 0.942 to 0.953, substantially exceeding the recommended threshold of 0.708. This is supported by a Cronbach's Alpha of 0.941 and a Composite Reliability of 0.962, both indicating excellent internal consistency. The AVE of 0.895 further confirms strong convergent validity, as the construct explains nearly 90% of the variance in its indicators. Similarly, the Infrastructure (X2) construct demonstrates excellent psychometric properties, with loadings between 0.947 and 0.960, an Alpha of 0.950, CR of 0.967, and an AVE of 0.908, signifying a highly reliable and well-defined construct.

The endogenous constructs also exhibit outstanding measurement quality. Teacher Digital Competence (Y1) shows the highest reliability scores in the model. The indicator loadings are all above 0.964, with one reaching 0.977. The Cronbach's Alpha and Composite Reliability values of 0.967 and 0.978, respectively, reflect near-perfect internal consistency. An AVE of 0.938 is remarkably high, indicating that the construct accounts for over 93% of the variance in its measures, establishing it as a supremely cohesive latent variable. For the final dependent variable, Learning Quality (Y2), the loadings (0.944 to 0.961), Alpha (0.949), CR (0.967), and AVE (0.908) are all well above their respective benchmarks, confirming a reliable and valid measurement scale.

Collectively, the results for all four constructs meet and far surpass the widely accepted criteria for a satisfactory measurement model in Partial Least Squares Structural Equation Modeling (PLS-SEM). According to Hair et al. (2019), indicator loadings should be above 0.708, Composite Reliability should exceed 0.70, and AVE should be greater than 0.50 to confirm convergent validity. Every construct in this model comfortably exceeds these thresholds, with AVE values significantly above 0.50 and reliability coefficients above 0.90. This indicates minimal measurement error and confirms that the items are highly representative of their intended theoretical constructs.

Therefore, the measurement model is deemed to have strong psychometric properties. The high levels of convergent validity and reliability established here provide a solid and statistically sound foundation. This validates the use of these measured indicators to represent their respective latent constructs, allowing for a confident and unambiguous interpretation of the subsequent structural model analysis that tests the hypothesized relationships between Teacher's Knowledge, Infrastructure, Teacher Digital Competence, and Learning Quality.

**2. Structural Model Evaluation (Inner Model)**

After confirming the adequacy of the measurement model, the structural (inner) model was assessed to evaluate the predictive accuracy and effect sizes of the proposed relationships. The evaluation focused on the coefficient of

determination ($R^2$) to measure the explanatory power of the endogenous constructs and the effect size ($f^2$) to determine the relative contribution of each exogenous variable to the model.

Table 1 Coefficient of Determination ($R^2$)

| Endogenous Variable | $R^2$ |
|---|---|
| Teachers' Digital Competence | 0.58 |
| Learning Quality | 0.69 |

The coefficient of determination ($R^2$) indicates the proportion of variance explained by the predictor variables in each endogenous construct. As shown in Table 2, teachers' digital competence achieved an $R^2$ value of 0.58, meaning that 58% of its variance is explained jointly by teachers' knowledge of educational technology and school facilities and infrastructure. According to commonly accepted PLS-SEM guidelines (0.25 = weak, 0.50 = moderate, 0.75 = substantial), this value represents a moderate level of predictive accuracy. This finding suggests that both individual competence factors and environmental support play meaningful roles in shaping teachers' digital capability.

Furthermore, learning quality obtained an $R^2$ value of 0.69, indicating that 69% of its variance is explained by teachers' knowledge of educational technology, school facilities and infrastructure, and teachers' digital competence. This value approaches the substantial category, demonstrating strong explanatory power of the model. It implies that the integrated framework effectively captures the main determinants of learning quality, confirming that the combination of technological knowledge, institutional support, and digital competence provides a comprehensive explanation of instructional effectiveness in border schools.

Table 2 Effect Size ($f^2$)

| Path | $f^2$ | Effect Size |
|---|---|---|
| Teacher's Knowledge → Teachers Digital Competence | 0.27 | Medium |
| Facilities → Teachers Digital Competence | 0.31 | Medium |
| Teacher's Knowledge → Learning Quality | 0.08 | Small |
| Facilities → Learning Quality | 0.07 | Small |
| Teachers Digital Competence → Learning Quality | 0.36 | Large |

The effect size ($f^2$) evaluates how strongly each exogenous variable contributes to changes in the $R^2$ value of an endogenous construct. Table 3 shows that both teachers' knowledge of educational technology ($f^2 = 0.27$) and school facilities and infrastructure ($f^2 = 0.31$) exert medium effects on teachers' digital competence. This indicates that these two factors are equally important predictors of digital competence development. In other words, strengthening teachers' technological understanding and improving school resources both substantially enhance teachers' ability to utilize digital tools effectively.

In contrast, the direct effects of technological knowledge ($f^2 = 0.08$) and infrastructure ($f^2 = 0.07$) on learning quality are small, while teachers' digital competence demonstrates a large effect ($f^2 = 0.36$). This pattern suggests that digital competence is the most influential determinant of learning quality and serves as the primary mechanism through which knowledge and facilities translate into improved instructional outcomes. These results reinforce the

mediating role of digital competence and highlight that investments in technology and infrastructure are most effective when accompanied by the development of teachers' digital skills.

### 3. Hypothesis Testing

The significance of relationships was evaluated through bootstrapping, which generated path coefficients along with their corresponding t-statistics and p-values. Significance was established using the thresholds of $t > 1.96$ and $p < 0.05$.

Table 3 Path Coeficients (Direct Effects)

| | Original sample (O) | T statistics (\|O/STDEV\|) | P values | Conclusion |
|---|---|---|---|---|
| **Teacher Knowledge -> Teacher Digital Competence** | 0,461 | 4,405 | 0,000 | H1 Accepted |
| **Infrastructure -> Teacher Digital Competence** | 0,375 | 4,067 | 0,000 | H2 Accepted |
| **Teacher Knowledge -> Learning Quality** | 0,252 | 2,095 | 0,036 | H3 Accepted |
| **Infrastructure -> Learning Quality** | 0,283 | 2,239 | 0,025 | H4 Accepted |
| **Teacher Digital Competence -> Learning Quality** | 0,436 | 3,572 | 0,000 | H5 Accepted |

The results of the direct effects hypothesis testing, presented in Table 4, reveal that all five proposed relationships are statistically significant, thereby supporting hypotheses H1 through H5. The analysis demonstrates that both antecedent variables, Teacher Knowledge ($\beta = 0.461$, $p < 0.001$) and Infrastructure ($\beta = 0.375$, $p < 0.001$), exert strong, positive, and significant direct effects on Teacher Digital Competence. Furthermore, all three predictors have a significant direct influence on the dependent variable, Learning Quality. Notably, Teacher Digital Competence itself shows the strongest direct effect on Learning Quality ($\beta = 0.436$, $p < 0.001$), underscoring its critical role as a key driver of educational outcomes.

In addition to the pivotal role of digital competence, the findings confirm that Teacher Knowledge ($\beta = 0.252$, $p = 0.036$) and Infrastructure ($\beta = 0.283$, $p = 0.025$) also contribute directly and positively to Learning Quality. The positive path coefficients indicate that improvements in teachers' subject mastery and the availability of adequate facilities and technological tools are associated with enhanced learning quality, independent of their effect through digital competence. These significant direct paths suggest a multifaceted model where Learning Quality is concurrently shaped by foundational resources

(Infrastructure), pedagogical expertise (Teacher Knowledge), and the pivotal mediating capability of Teacher Digital Competence.

Table 4 Indirect Effects (Mediation)

| | Original Sample (O) | T statistics (\|O/STDEV\|) | P values | Conclusion |
|---|---|---|---|---|
| **Teacher Knowledge -> Teacher Digital Competence -> Learning Quality** | 0,201 | 2,721 | 0,007 | H6 Accepted |
| **Infrastructure -> Teacher Digital Competence -> Learning Quality** | 0,163 | 2,552 | 0,011 | H7 Accepted |

The results in Table 5 confirm the significant mediating role of Teacher Digital Competence in the relationships examined. Both indirect paths tested are statistically significant, as evidenced by their bootstrapped t-statistics exceeding the critical value of 1.96 and p-values below the 0.05 threshold. Specifically, Teacher Knowledge exerts a significant positive indirect effect on Learning Quality through Teacher Digital Competence ($\beta = 0.201$, $p = 0.007$). Similarly, Facilities & Infrastructure also has a significant positive indirect effect on Learning Quality, mediated by Teacher Digital Competence ($\beta = 0.163$, $p = 0.011$). These findings support hypotheses H6 and H7, indicating that a substantial portion of the influence from both antecedent variables on the final outcome is channeled through the enhancement of teachers' digital capabilities.

This mediation analysis elucidates the mechanism through which Teacher Knowledge and Facilities & Infrastructure ultimately improve Learning Quality. The significant indirect effects suggest that the positive impact of foundational teacher expertise and adequate physical resources is not merely direct but is significantly amplified when they contribute to building stronger digital competencies. Consequently, Teacher Digital Competence functions as a pivotal conduit, translating foundational inputs into enhanced instructional quality and student learning outcomes. These results underscore the importance of developing digital competence as a strategic target for interventions aimed at leveraging teacher knowledge and institutional infrastructure to improve overall educational quality.

## DISCUSSION

The findings of this study demonstrate that teachers' knowledge of educational technology plays a crucial role in strengthening teachers' digital competence. This result supports the Technological Pedagogical Content Knowledge (TPACK) perspective, which argues that effective teaching emerges when educators are able to integrate technology with pedagogy and subject content (Mishra & Koehler, 2006). Teachers who possess adequate technological understanding are more capable of selecting appropriate digital tools, designing interactive learning experiences, and adapting instructional strategies to diverse classroom needs. In the context of border schools, where access to professional development is often limited, such knowledge becomes an essential foundation for enabling teachers to adopt technology meaningfully rather than superficially. This finding is consistent with previous studies indicating that technological

knowledge enhances teachers' readiness and confidence to implement digital learning practices.

This study also highlights the importance of school facilities and infrastructure as environmental enablers of technology integration. Adequate access to computers, internet connectivity, and instructional media allows teachers to transform their technological knowledge into actual classroom practice. Without sufficient resources, even competent teachers may face barriers to innovation and struggle to implement digital instruction effectively. This aligns with educational facilities theory, which emphasizes that physical and technological resources directly influence instructional performance (Bafadal, 2008; Hanafi, 2015). The present findings reinforce earlier research showing that supportive infrastructure improves teacher performance and student engagement, particularly in underserved schools where resource limitations are often the primary obstacle to educational quality.

Another important outcome is the central role of teachers' digital competence in improving learning quality. The results indicate that digital competence is not merely a complementary skill but a key determinant of effective instruction. Teachers who are digitally competent are better able to manage online and offline learning environments, create multimedia materials, facilitate collaboration, and maintain student engagement. These capabilities contribute directly to more structured, interactive, and meaningful learning processes. This evidence supports digital competence theory (Ferrari et al., 2012) and confirms prior studies suggesting that digital literacy and instructional technology skills are strongly associated with enhanced learning outcomes. Therefore, improving digital competence should be considered a strategic priority for schools seeking to raise instructional standards.

Finally, this study reveals that digital competence functions as an explanatory mechanism linking both technological knowledge and infrastructural support to learning quality. While knowledge and facilities provide necessary inputs, their impact becomes significant only when teachers are able to apply them effectively through digital skills. This mediating role clarifies why investments in technology alone do not automatically improve educational outcomes. Particularly in border and disadvantaged contexts, capacity building for teachers appears to be more critical than merely expanding physical resources. By integrating individual competence and organizational support within a single framework, this study contributes theoretically to the literature on educational technology and offers practical implications for policymakers to prioritize teacher training alongside infrastructure development to achieve sustainable improvements in learning quality.

## CONCLUSIONS AND RECOMMENDATIONS

### 1. Conclusions

This study examined the relationships among teachers' knowledge of educational technology, school facilities and infrastructure, teachers' digital competence, and learning quality within elementary schools located in a border region. The findings confirm that both individual and institutional factors play complementary roles in improving instructional effectiveness. Teachers'

knowledge of educational technology and the availability of adequate facilities contribute significantly to the development of teachers' digital competence, which in turn enhances learning quality. These results indicate that digital competence functions as a key mechanism that translates technological knowledge and environmental support into meaningful improvements in classroom practice.

Furthermore, digital competence emerges as the most influential determinant of learning quality, serving not only as a direct predictor but also as a mediator between technological resources and educational outcomes. This finding suggests that the success of technology integration depends less on the mere presence of digital tools and more on teachers' ability to utilize them pedagogically. By providing empirical evidence from underrepresented border schools, this study enriches the educational technology literature and demonstrates that strengthening teacher capacity is essential for achieving sustainable learning improvement in disadvantaged contexts.

**2. Recommendations**

Based on these conclusions, several practical implications can be proposed. Schools and policymakers should prioritize continuous professional development programs focused on enhancing teachers' digital competence, including training in instructional technology integration, digital classroom management, and the development of interactive learning media. Such programs should move beyond basic technical training and emphasize pedagogical applications of technology to ensure that digital tools directly support learning objectives. Strengthening teachers' competencies is likely to yield greater educational benefits than technology procurement alone.

Educational stakeholders should ensure equitable provision of facilities and infrastructure, particularly in remote and border areas. Investments in reliable internet access, digital devices, and multimedia resources are necessary to create supportive learning environments where teachers can apply their competencies effectively. Finally, future initiatives should adopt an integrated strategy that simultaneously develops technological knowledge, teacher competence, and institutional support. This comprehensive approach will maximize the impact of educational technology implementation and contribute to long-term improvements in learning quality.

## ADVANCED RESEARCH

Despite providing meaningful empirical contributions, this study has several limitations that should be acknowledged. The research employed a cross-sectional design in which data were collected at a single point in time. Although this approach is suitable for examining structural relationships among variables, it limits the ability to establish causal inferences and observe changes in teachers' competence and learning quality over time. Digital competence development is inherently dynamic and may evolve with continuous training, technological exposure, and institutional support. Therefore, longitudinal studies are needed to capture the long-term effects of technology integration and to better understand how improvements in competence gradually influence instructional outcomes.

This study relied primarily on self-reported questionnaire data, which may introduce common method bias and social desirability effects. Teachers might overestimate their technological knowledge or digital competence when responding to survey items. Although reliability and validity tests confirmed acceptable measurement quality, future research could strengthen objectivity by incorporating multiple data sources, such as classroom observations, performance assessments, or student achievement records. Combining perceptual and behavioral measures would provide a more comprehensive evaluation of how digital competence translates into actual teaching practices and learning effectiveness.

The study focused specifically on elementary schools located in border and disadvantaged areas. While this niche sample provides valuable insights into underrepresented educational contexts, it may limit the generalizability of the findings to urban or well-resourced schools. Educational environments with different technological readiness and organizational cultures may demonstrate different patterns of relationships among knowledge, infrastructure, competence, and learning quality. Future research should replicate the proposed model across diverse regions, educational levels, and institutional settings to compare results and enhance external validity.

This study examined digital competence as the primary mediating variable, yet other potential mechanisms may also influence learning quality. Factors such as teachers' motivation, organizational support, leadership, professional collaboration, or digital attitudes could interact with technological knowledge and infrastructure. Future studies are encouraged to extend the model by incorporating additional variables, testing moderating or multiple mediation effects, or applying mixed-methods approaches to explore contextual nuances. Such advancements would enrich theoretical understanding and provide more comprehensive strategies for optimizing educational technology implementation.

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