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LINKING THE DIGITAL COMPETENCE OF SUPERVISORS' AND TEACHERS' DEVELOPMENT THROUGH THE IMPLEMENTATION OF DIGITAL-BASED SUPERVISION

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ABSTRACT

This study examines how supervisors' digital competence influences teachers' digital competence through the implementation of digital-based supervision in South Sulawesi, Indonesia. A quantitative cross-sectional survey involved 318 participants from 78 senior high schools. Data were collected using validated instruments to measure supervisors' digital competence (ISTE Standards), the implementation of digitally based supervision quality (Cogan's clinical supervision model), and teachers' digital competence (DigComp 2.2). Findings revealed that Supervisor digital competence directly influences teacher digital competence ($\beta = 0.227$, $p = 0.006$) and strongly predicts implementation of digital-based supervision quality ($\beta = 0.702$, $p < 0.001$). The implementation of digital-based supervision quality significantly enhances teachers' digital competence ($\beta = 0.471$, $p < 0.001$). The indirect effect through implementation ($\beta = 0.331$, $p < 0.001$) exceeds the direct effect, indicating crucial mediation. The model explains 49.2% of the variance in implementation quality and 42% of the variance in teacher digital competence. This demonstrates that supervisors' digital competence alone is insufficient. It must be operationalized through systematic implementation to meaningfully develop teacher competencies. Four pathways link supervisor digital competence dimensions to implementation phases: system designer to preparation, empowering leader to observation, advocate for digital citizenship to conferencing, and visionary planner to follow-up. Educational policymakers should prioritize standardized digital supervision frameworks, address infrastructure barriers, and shift professional development from competence-building to implementation-focused training.

KEYWORDS: Supervisor Digital Competence, Teacher Digital Competence, Digital-Based Supervision, Mediation Analysis, Educational Technology Leadership.

1. INTRODUCTION

Educational supervision has long supported teacher professional development, traditionally centered on classroom observation and evaluative feedback (Das, 2020; Ismail, 2018). However, digital transformation has expanded teaching demands, requiring teachers to develop comprehensive digital competence across information literacy, communication, content creation, security, problem-solving, and digital citizenship (Vuorikari et al., 2022b). These competencies are essential for technology integration and preparing students for 21st-century learning (Ardiansyah & Trihantoyo, 2023; Basilotta-Gómez-Pablos et al., 2022), yet significant gaps persist, especially in developing contexts where digital infrastructure and training remain limited (Batanero et al., 2020; Starkey, 2020).

To address these gaps, supervision has evolved into digital-based supervision, a contemporary adaptation, with Cogan's (1973) clinical supervision model that utilizes digital platforms, virtual observation tools, and LMS-based feedback systems. This approach improves flexibility and efficiency across preparation, observation, conferencing, and follow-up phases (Astuti et al., 2024; Ekawaty et al., 2024). More than an evaluative process, digital-based supervision provides continuous coaching, targeted feedback, and automated monitoring that accelerate competence growth (AlAjmi, 2022; Antonopoulou et al., 2025).

The effectiveness of digital-based supervision implementation (IDBS) is strongly influenced by supervisors' digital competence (SDC). Rasdiana et al. (2024) found that supervisors' digital leadership directly shapes teachers' technology adoption, while (Hamzah et al., 2025a; Rahyasih et al., 2024; Ruhmi & Yuliana, 2025) confirm that higher SDC enhances supervision quality and teacher development. This possible reciprocal relationship can be further explained by the Technology Acceptance Model (TAM) (Davis, 1989), which shows that supervisors with higher digital competence perceive technology as more useful and easier to use, improving implementation effectiveness and reinforcing their own competence. Similarly, the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003) highlights that performance expectancy, effort expectancy, social influence, and facilitating conditions encourage competent supervisors to adopt and sustain technology-based practices, further enhancing their skills through practice. Diffusion of Innovation Theory (Rogers, 2003) also explains that digitally competent supervisors accelerate the adoption of innovative supervision by modeling exemplary practices and fostering professional collaboration, which in turn strengthens their digital competence. These frameworks collectively support the reciprocal dynamic between supervisors' digital competence and effective digital-based supervision in enhancing teachers' digital competence.

Empirical studies show that high-quality IDBS, marked by structured preparation, systematic observation, and consistent follow-up—significantly improves teachers' digital competence (Bintang et al., 2024; Gallagher et al., 2024; Lavigne et al., 2023; Rusmaniar et al., 2023). However, research examining the integrated structural relationship among SDC, IDBS, and TDC remains limited. This gap is critical in developing regions, where uneven digital literacy, infrastructure constraints, and insufficient supervisor preparation hinder digital transformation (Batanero et al., 2020; Saltos-Rivas & Novoa-Hernández, Pavel Rodríguez, 2023; Starkey, 2020).

South Sulawesi exemplifies these challenges. Mahmudi et al. (2024) report inconsistent digital supervision characterized by weak preparation, non-standardized protocols, and limited follow-up. Supervisors also encounter resistance to changing traditional practices (Reis-Andersson, 2023), insufficient training (Al-Barakat et al., 2025), and systemic constraints that impede effective implementation (Rukanda & Nurhayati, 2023). To address these issues, this study examines how supervisors' digital competence influences teachers' digital competence through the mediating effect of digital-based supervision implementation. Using ISTE Standards for Leaders (ISTE, 2024) for SDC, the DigComp 2.2 framework (Vuorikari et al., 2022b) for TDC, and an adapted clinical supervision model (Cogan, 1973) for IDBS, the study employs a quantitative survey involving teachers and school leaders across South Sulawesi.

This research contributes theoretically by clarifying the mechanisms through which IDBS mediates the relationship between supervisors' and teachers' digital competence, specifically examining whether supervisors' digital proficiency translates into enhanced teacher competencies through digital supervision practices. Practically, this study informs the design of standardized digital supervision systems by identifying critical features and implementation strategies, and guides the development of targeted professional development programs that address specific competency gaps in information literacy, digital content creation, and problem-solving skills. These contributions support evidence-based digital transformation initiatives in Indonesian schools and provide a framework adaptable to educational contexts in other developing nations facing similar technological integration challenges.

1. LITERATURE REVIEW

2.1. *Brief Conceptual Framework*

Supervisors with strong digital competence can enhance teachers' digital competence by providing supportive infrastructure, digital platforms, and relevant learning resources (Antonopoulou et al., 2025). Their competence also enables effective use of digital supervision tools, such as classroom video recordings and LMS analytics that deliver fast and objective feedback (Bintang et al., 2024), consistent with TAM (Davis, 1989), which states that high competence increases perceived ease and usefulness of technology. Continuous and differentiated coaching becomes more effective when supervisors possess the necessary digital skills (AlAjmi, 2022), aligning with UTAUT's view that competent users demonstrate stronger performance and effort expectancy (Venkatesh et al., 2003). Moreover, competent supervisors act as early adopters who model digital practices and stimulate teacher adoption, as described in Diffusion of Innovation Theory (Rogers, 2003). As digital transformation requires clear standards to guide competence development and supervision quality (Peters et al., 2022), this study employs the ISTE Standards for Leaders to assess supervisors' digital competence and the DigComp framework to measure teachers' digital competence, with digital-based supervision, adapted with the clinical supervision model, serving as the mediator. These frameworks are increasingly important as teachers must strengthen digital skills to meet the demands of Industry 4.0 and Society 5.0 (Ibda et al., 2023), despite persistent infrastructural and digital literacy challenges (Mahmud et al., 2025).

2.2. *Teacher Digital Competence (Tdc)*

Teachers' digital competence is not limited to basic technical skills; rather, it is defined as the confident, critical, and responsible use of digital technologies in teaching, learning, and social participation (Basilotta-Gómez-Pablos et al., 2022). This competence encompasses information and data literacy, communication and collaboration, digital content creation, security (including digital well-being and cybersecurity), problem-solving, critical thinking, and ethical considerations (Norhagen et al., 2024; Vuorikari et al., 2022b). Teachers' digital competence is a set of knowledge, skills, and attitudes required for effectively utilizing information and communication technologies (ICT) across various dimensions, such as technological, informational, multimedia, communicative, collaborative, and ethical, while taking into account pedagogical-didactic criteria for the effective integration of ICT in educational practice (Tondeur et al., 2023).

Figure 1: Dig Comp Edu 2.2 Framework.

Figure 1 shows several digital competencies that teachers are expected to perform well (Vuorikari et al., 2022a). Information and data literacy is essential for teachers, as they must be able to search, organize, and use digital information to design relevant learning activities (Ghodoosi et al., 2023; Tomczyk, 2024). This competence in practice contributes to teaching effectiveness in terms of technology integration (Chan et al., 2025; Temirkhanova et al., 2024), the students' empowerment in personalized learning (Brazauskienė & Melnikova, 2024; Nguyen & Habók, 2024), and professional development for the long-term instructional quality (Nguyen & Habók, 2024; Sandoval-ríos et al., 2025). Effective communication and collaboration in digital spaces further enable teachers to build professional learning communities and accelerate the spread of best practices (Cao et al., 2025). In addition, teachers today must be capable of producing pedagogically sound and accessible digital learning materials, such as interactive videos, modules, and online quizzes, to ensure that digital learning becomes a transformative approach rather than a simple replacement of traditional methods (Basilotta-Gómez-Pablos et al., 2022). These practices must be supported by strong digital security awareness to protect student data, ensure ethical technology use, and maintain digital well-being (Weber et al., 2025). Teachers also require basic troubleshooting abilities, pedagogical adaptation skills, and critical thinking to integrate technology effectively and maintain learning continuity during technical challenges (Chiu et al., 2024).

However, even with growing emphasis on data literacy, digital content creation, and collaborative skills, many schools still face gaps between the digital competencies that teachers need and their current abilities, often due to the lack effectiveness in professional development efforts, such as supervisors' limited digital competence and the quality of digital-based supervision, including digital tools, observation and feedback practices, and targeted professional development (Domínguez-gonzález et al., 2025; Ekawaty et al., 2024). Consequently, school leaders and supervisors play a crucial role: strong technology leadership, effective online instructional supervision, and a supportive digital culture not only enhance teachers' digital competence (Althubyani, 2024) but also foster professional growth, strengthen digital communication, and promote sustained integration of technology into learning (Althubyani, 2024; Mahmudi et al., 2024), which will be elaborated further in the following section.

2.3. *Supervisor Digital Competence (Sdc)*

Supervisor digital competence in education refers to the knowledge, skills, and attitudes required by educational supervisors, such as schools' principals and education supervisor under government authority, to effectively lead, support, and evaluate digital transformation in schools (Hamzah et al., 2025a). Supervisor digital competence consists of several indicators adapted from the ISTE framework, namely: (1) advocate for equity and citizenship, (2) visionary planner, (3) empowering leader, (4) system designer, and (5) connected learner (ISTE, 2024) (see Figure 2). Based on these five indicators, four specific measures are developed to assess supervisor digital competence: (1) leadership strategies in educational technology (system designer); (2) fostering a digital school culture (supervisor as an advocate for citizenship in digital education); (3) teacher coaching in learning technologies (empowering leader); and (4) preparing students for the digital era (visionary planner).

Figure 2: International Society for Technology in Education (ISTE) Standard for Leaders.

Figure 2 shows several adopted competencies that are expected to help teachers in developing their digital competence. Supervisors as advocates for digital citizenship ensure that all school members, including students and teachers, have equitable access to digital resources, promote ethical practices and data security, and foster a responsible digital culture that prevents widening gaps or privacy risks (Alenezi & Alfaleh, 2024). Visionary supervisors set medium- to long-term digital strategies, aligning technology use with curriculum goals, prioritizing impactful investments, and fostering sustainable cultural change, which directly influences the pace and quality of teachers' technology integration (Witthöft et al., 2024). Empowering supervisors provides coaching, mentoring, opportunities for experimentation, and constructive feedback, enhancing teachers' confidence in using digital tools, promoting lifelong learning, and accelerating practical skill development (Rasdiana et al., 2024). As system designers, supervisors develop infrastructure (e.g., LMS, repositories, data policies) and digital supervision procedures (e.g., video observation, learning analytics), while continuously updating their own skills as connected learners, serving as role models for professional development (Witthöft et al., 2024).

Digitally competent supervisors have a direct impact on teachers' professional digital competence by modeling best practices, providing guidance, and setting clear expectations that encourage teachers to adopt and integrate technology into instruction (Astuti et al., 2024; Rahyasih et al., 2024). They can tailor digital supervision to individual teacher needs, enhancing the implementation effectiveness of digital-based supervision and promoting overall professional growth (Hamzah et al., 2025b; Kaomaroeng et al., 2024; Riski et al., 2023). However, challenges remain, including supervisors' resistance to change, preference for traditional methods, limited access to comprehensive and ongoing digital training, staff reluctance to adopt new technology, and heavy workloads that constrain professional development opportunities (Al-Barakat et al., 2025; Arina et al., 2025; Reis-Andersson, 2023; Rukanda & Nurhayati, 2023). Addressing these barriers is crucial to ensure that supervisors can effectively support teachers' digital competence and sustain digital transformation in schools.

2.4. Implementation Of Digital-Based Supervision (Idbs)

Digital-based supervision refers to the use of technologies such as online platforms, video conferencing, data analytics, and digital feedback tools to conduct, monitor, and support educational supervision. This method integrates traditional supervisory principles with digital tools, enabling real-time collaboration, observation, and feedback regardless of physical distance (Handayani, 2024; Nisa et al., 2024). Digital supervision adapts core elements of clinical supervision, including relationship-building, joint planning, observation, analysis, conferencing, and follow-up (Cogan, 1973). In this regard, we divide into four essential stages: (1) quality of digital supervision preparation, (2) quality of digital observation, (3) digital post-observation conferencing, and (4) quality of digital follow-up and support.

Adequate preparation reduces technical disruptions, clarifies assessment criteria, and ensures that collected data can be used effectively (Lavigne et al., 2023). High-quality digital observations allow supervisors to review key moments, compare practices across time, and use rubrics or peer reviews to provide meaningful insights for teacher improvement (Zeeb et al., 2024). Digital conferencing—whether synchronous or asynchronous—supports deeper reflection, documented discussions, and actionable plans, with structured post-observation feedback shown to significantly improve teaching practices (Amemasor et al., 2025; Lavigne et al., 2023). Sustained digital support, including follow-up analytics and ongoing feedback, reinforces long-term changes in teachers' digital and instructional practices (Gallagher et al., 2024).

However, implementation of digital supervision in many schools remains suboptimal due to inadequate preparation, non-standardized observations, unstructured post-conferences, and inconsistent follow-up. Consequently, its potential to enhance teachers' digital competence is not fully realized (Mahmudi et al., 2024). Limited digital skills among supervisors and teachers, combined with insufficient training and challenges faced by senior staff, further hinder effective implementation (Opesemowo et al., 2024). Despite these challenges, digital supervision is increasingly essential in response to widespread educational digitalization and the need to support remote and hybrid learning environments (Sitorus et al., 2023). It expands supervisory access, especially for remote or underserved schools that enables flexible scheduling, and provides continuous support, which in turn helps teachers in isolated areas improve their digital competence (Nisa et al., 2024). Achieving optimal results requires adequate infrastructure, digital literacy training, data privacy safeguards, and sustained support from both supervisors and teachers (Handayani, 2024).

Drawing on the theoretical and conceptual framework explained above, we for-mulated the following hypotheses (see Figure 3).

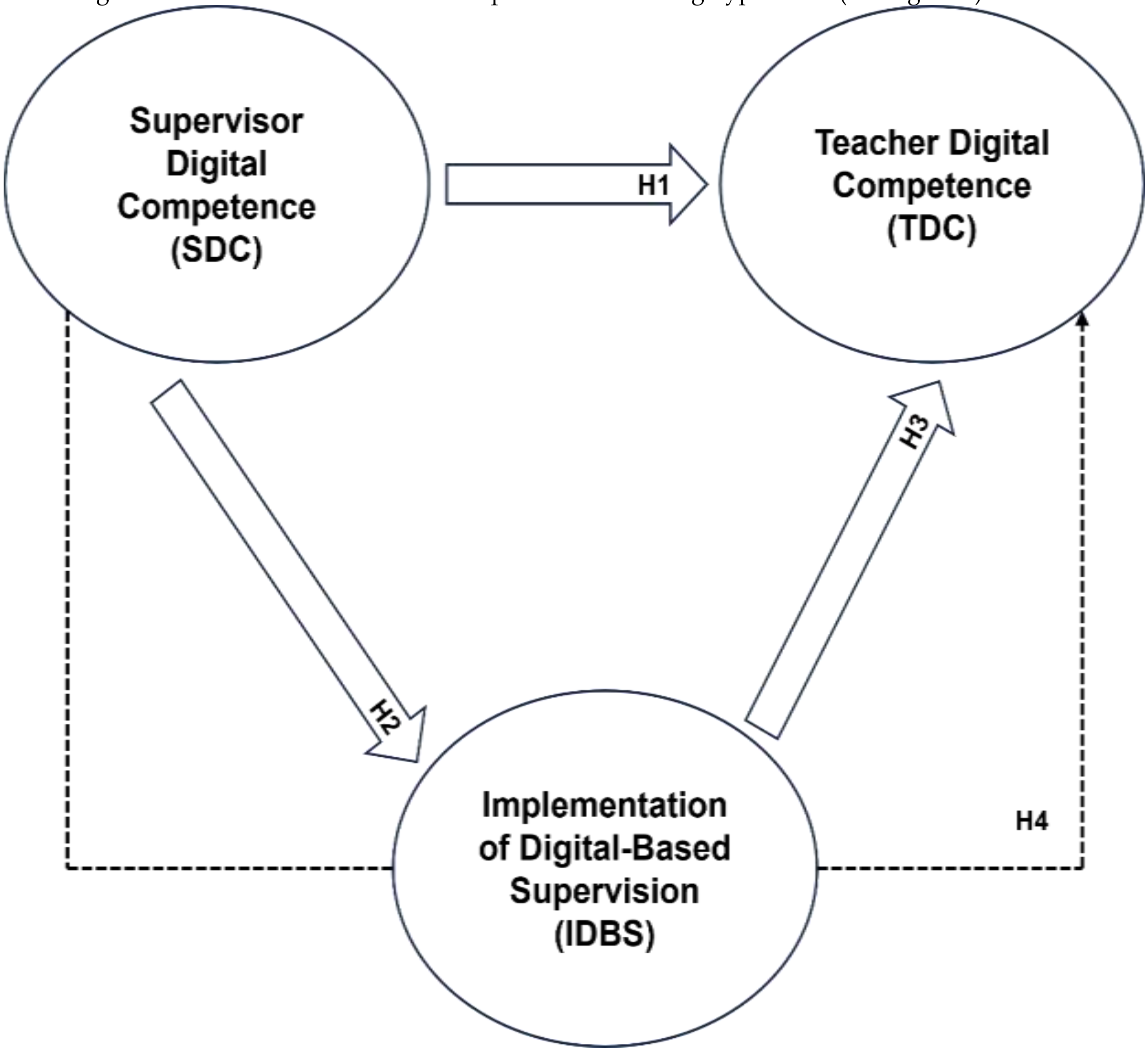

Figure 3: Conceptual Model and Hypotheses Development.
[Notes: H1= SDC Significantly Influences TDC; H2= SDC Significantly Influence IDBS; H3= IDBS Significantly Influences TDC; And H4; SDC Significantly Influences TDC Through Mediation Of IDBS]

2. METHODS

3.1. Research Design

This research used a quantitative approach to explore a central question: How do supervisors' digital competencies influence teachers' digital abilities, and does this effect occur through the implementation of digital-based supervision? We employed a cross-sectional survey design, collecting all data at a single point in time, because this method is well-suited for examining relationships among variables and statistically testing theoretical assumptions (Demir & Usak, 2025; Hair et al., 2022). To analyze the data, we used Partial Least Squares Structural Equation Modeling (PLS-SEM), selected for its ability to handle complex relationships among multiple variables, its strong predictive capabilities, and its capacity to assess both measurement and structural models simultaneously (Afthanorhan, 2013; Cardella et al., 2021; Sarstedt et al., 2021). Ultimately, this study tests the proposition that digitally competent supervisors are more likely to deliver high-quality digital-based supervision, which in turn enhances teachers' digital competencies.

Participants And Data Collection Procedures

This study involved educational stakeholders who directly participate in or experience supervisory processes within senior high schools in South Sulawesi Province, Indonesia. All participants (principals, vice principals, and teachers) responded to the complete survey instrument covering all three constructs (SDC, IDBS, and TDC). This approach was deliberately chosen because all stakeholder groups directly experience supervisory processes and can provide informed assessments of supervisor digital competence through observed behaviors and leadership practices, implementation quality through their participation in digital supervision activities, and teacher digital competence through self-assessment (for teachers) or observed professional practices (for principals and vice principals). This multi-perspective approach strengthens construct validity by triangulating perceptions across different organizational roles rather than relying solely on self-reported supervisor competence or teacher-only assessments.

Data were collected through a cross-sectional survey administered between August 4 and September 5, 2025. Prior to the main data collection, a pilot test was conducted at a comparable institution to refine item clarity and technical functionality. Following approvals from the South Sulawesi Education Authority and participating school administrations, the final survey was distributed electronically using Google Forms. A convenience sampling strategy was used based on accessibility and willingness to participate, with emphasis on schools already implementing digital supervision to ensure respondents had sufficient experience with the phenomena under investigation.

A total of 318 valid responses were obtained from participants across 17 of the 24 regencies (approximately 78 schools), representing a response rate of 71%, which is acceptable for quantitative survey research in educational settings (Hair et al., 2021). Teachers comprised the largest proportion of respondents (73.58%), followed by principals (16.98%) and vice principals (9.43%). Participants' educational backgrounds included bachelor's degrees (72.96%), master's degrees (25.79%), and doctoral degrees (1.26%). Professional experience ranged from 0–5 years (35.22%), 6–10 years (24.53%), 11–15 years (27.04%), and more than 15 years (13.21%). Supervision frequency varied across respondents: monthly (45.60%), every 2–3 months (24.53%), semi-annually (9.12%), annually (0.31%), and irregularly (20.44%). The diversity in roles, educational qualifications, professional experience, and exposure to supervision processes supports the suitability of the sample for examining the proposed relationships among SDC, IDBS, and TDC within South Sulawesi's varied educational contexts.

Convenience sampling was employed due to practical constraints including limited accessibility to geographically dispersed schools across South Sulawesi's 24 regencies, time and resource limitations for comprehensive random sampling, and the need to prioritize schools with existing digital supervision implementation to ensure respondents had sufficient experience with the phenomena under investigation. While this approach limits statistical generalizability, it was appropriate for this exploratory study examining complex relationships in an understudied context. The diverse representation across 17 regencies and 78 schools, combined with variation in participant roles, experience levels, and supervision exposure, enhances the ecological validity of our findings within similar developing educational contexts.

3.2. *Measurements*

This study used questionnaires as the primary data collection tool, carefully designed following established best practices in digital competence assessment and educational research. Before the main data collection, the instrument underwent prior evaluation through pilot testing to ensure validity and reliability. All items were measured using a 5-point Likert scale ranging from strongly disagree (1) to strongly agree (5), enabling standardized and reliable assessment across all constructs.

The instrument design was systematically built upon three interconnected theoretical frameworks. First, we measured Supervisors' Digital Competence (SDC) using the ISTE Standards for Leaders (ISTE, 2024), adapted into four indicators: leadership strategies in educational technology, fostering a digital school culture, teacher coaching in learning technologies, and preparing students for the digital era (Alenezi & Alfaleh, 2024; Nisa et al., 2023, 2024; Norhagen et al., 2024; Rasdiana et al., 2024; Sutrisno et al., 2024; Witthöft et al., 2024). Second, we assessed Teachers' Digital Competence (TDC) through the DigComp 2.2 framework (Vuorikari et al., 2022b), organized into six areas: information and data literacy, communication and collaboration, digital content creation, security, problem-solving, and digital citizenship and professionalism (Althubyani, 2024; Basilotta-Gómez-Pablos et al., 2022; Cao et al., 2025; Chiu, 2021; Domínguez-gonzález et al., 2025; Mahmudi et al., 2024; Tomczyk, 2024; Tondeur et al., 2023; Weber et al., 2025). Third, we operationalized the Implementation of Digital-Based Supervision (IDBS) by adapting Cogan's (1973) clinical supervision model into four phases: quality of digital supervision preparation, quality of digital observation, digital post-observation conferencing, and quality of digital follow-up and support (Amemasor et al., 2025; Ekawaty et al., 2024; Gallagher et al., 2024; Handayani, 2024; Lavigne et al., 2023; Mahmudi et al., 2024; Nisa et al., 2024; Sitorus et al., 2023; Zeeb et al., 2024).

The integration of these frameworks was theoretically grounded in TAM (Davis, 1989), UTAUT (Venkatesh et al., 2003), and Diffusion of Innovation Theory (Rogers, 2003), which collectively explain how the proposed objectives of supervisors' digital competence influence technology adoption and supervision effectiveness. By systematically connecting supervisor competence, supervision quality, and teacher outcomes, our instrument captures the complete pathway through which digital transformation occurs in schools. The complete survey instrument, including all operational definitions and specific items for each variable (see Appendix).

Table 1: Pilot Testing of the Measured Variables Instruments.

n= 80												
Items code		Factor loading (>0.60)		Communality (>0.50)		KMO (>0.50)	Variance (>50%)		Anti-image correlations (>0.50)		Cronbach alpha (>0.70)	CMB (<50%)
	cont.		cont.		cont.			cont.		cont.		
SDC1	IDBS9	0,785	0,867	0,981	0,950		60,941	97,319	.762[a]	.940[a]	0.971 (SDC)	30.098
SDC2	IDBS10	0,790	0,856	0,967	0,950		68,725	97,622	.830[a]	.930[a]	0.982 (IDBS)	
SDC3	IDBS11	0,733	0,865	0,939	0,986		73,340	97,909	.883[a]	.756[a]	0.964 (TDC)	
SDC4	IDBS12	0,663	0,865	0,897	0,986		76,862	98,175	.772[a]	.791[a]		
SDC5	IDBS13	0,836	0,876	0,962	0,954		79,265	98,420	.924[a]	.937[a]		
SDC6	IDBS14	0,730	0,856	0,944	0,970		81,522	98,642	.829[a]	.861[a]		
SDC7	IDBS15	0,805	0,834	0,959	0,962		83,191	98,843	.880[a]	.878[a]		
SDC8	IDBS16	0,781	0,855	0,900	0,986		84,690	98,990	.903[a]	.770[a]		
SDC9	TDC1	0,760	0,756	0,991	0,941	0.839	86,002	99,126	.704[a]	.786[a]		
SDC10	TDC2	0,769	0,620	0,993	0,931		87,114	99,248	.714[a]	.726[a]		
SDC11	TDC3	0,749	0,607	0,988	0,915		88,210	99,356	.723[a]	.755[a]		
SDC12	TDC4	0,783	0,780	0,970	0,938		89,203	99,454	.806[a]	.891[a]		
SDC13	TDC5	0,790	0,747	0,984	0,917		90,111	99,542	.792[a]	.919[a]		
SDC14	TDC6	0,776	0,642	0,881	0,956		90,980	99,621	.914[a]	.740[a]		
SDC15	TDC7	0,853	0,599	0,961	0,912		91,788	99,698	.868[a]	.841[a]		
SDC16	TDC8	0,845	0,689	0,936	0,894		92,461	99,761	.926[a]	.938[a]		
SDC17	TDC9	0,805	0,813	0,976	0,954		93,125	99,816	.794[a]	.840[a]		
IDBS1	TDC10	0,780	0,630	0,913	0,864		93,754	99,861	.933[a]	.889[a]		
IDBS2	TDC11	0,760	0,763	0,952	0,960		94,343	99,896	.765[a]	.857[a]		
IDBS3	TDC12	0,849	0,765	0,965	0,956		94,889	99,926	.953[a]	.862[a]		
IDBS4	TDC13	0,834	0,749	0,983	0,964		95,386	99,949	.820[a]	.832[a]		
IDBS5	TDC14	0,884	0,785	0,981	0,966		95,847	99,969	.840[a]	.877[a]		
IDBS6	TDC15	0,844	0,755	0,970	0,966		96,245	99,986	.865[a]	.783[a]		
IDBS7	TDC16	0,863	0,508	0,978	0,702		96,626	99,997	.783[a]	.954[a]		
IDBS8	TDC17	0,814	0,595	0,931	0,839		96,996	100,000	.910[a]	.924[a]		

Table 1 presents pilot testing (n = 80) evaluated 50 items across three constructs: Supervisor Digital Competencies (SDC), Implementation of Digital-Based Supervision (IDBS), and Teacher Digital Competencies (TDC). Following Hair et al.'s (Hair et al., 2021) recommendation that communality values should comfortably exceed 0.50 to ensure adequate shared variance, a conservative screening approach was applied, leading to the exclusion of three items—TDC7 (communality = 0.912 but loading = 0.599), TDC16 (communality = 0.702 but loading 0.508), and TDC17 (communality = 0.839 but loading = 0.595)—due to marginal psychometric performance and to prioritize measurement precision. The remaining 47 items demonstrated strong psychometric adequacy, with factor loadings ranging from 0.663 to 0.884, communalities, KMO values 0.839, and anti-image correlations ranging from 0.704 to 0.954, all surpassing recommended thresholds (Hair et al., 2021; Kaiser, 1974).

Reliability analysis showed excellent internal consistency across constructs, with Cronbach's alpha values ranging from 0.964 to 0.982. Additionally, Common Method Bias (CMB) was within acceptable limits (e.g., 30.098), further confirming the instrument's validity (Podsakoff et al., 2003). This refinement ensured that all retained items exhibited unambiguous psychometric strength, resulting in a validated 47-item instrument for main data collection.

3.3. *Data Analysis*

The data were analyzed using SPSS version 25.0 for preliminary analyses, including descriptive statistics evaluated against established criteria (means > 3.5 indicating agreement on 5-point Likert scales per Pett et al., (2003); skewness within ±2 and kurtosis within ±7 indicating normality, and Harman's single-factor test to assess common method bias with results required below 50% (Podsakoff et al., 2003). Subsequent analyses employed SmartPLS version 3.0 following Confirmatory Composite Analysis (CCA) procedures (Hair et al., 2020; Schuberth, 2021), as PLS-SEM efficiently analyzes complex relationships among latent variables in prediction-oriented, cross-sectional survey research.

The measurement model was evaluated through internal consistency using Composite Reliability (CR ≥ 0.70 acceptable, ≥ 0.90 excellent per Hair et al., (Hair et al., 2021), convergent validity via factor loadings ≥ 0.60 for exploratory research (Dash & Paul, 2021; Sarstedt et al., 2021) with ≥ 0.708 ideal and AVE ≥ 0.50 (Fornell & Larcker, 1981), and discriminant validity using the Fornell-Larcker criterion requiring square root of AVE to exceed inter-construct correlations (Fornell & Larcker, 1981), and HTMT ratios < 0.85 (Henseler et al., 2015). Structural model evaluation interpreted path coefficients using Cohen's (1988) effect size guidelines ($|\beta| \geq 0.02$ small, ≥ 0.15 medium, ≥ 0.35 large), with significance assessed through bootstrapping (5,000 resamples) requiring t-statistics > 1.96 and p-values < 0.05 for 95% confidence (Hair et al., 2021; Henseler et al., 2015), while mediation effects were examined by comparing direct and indirect path coefficients. Finally, model predictive accuracy was assessed using R^2 (coefficient of determination), f^2 (effect size), and Q^2 (predictive relevance). R^2 values were interpreted as substantial (≥ 0.75), moderate (≥ 0.50), or weak (≥ 0.25), while f^2 values were evaluated as large (≥ 0.35), medium (≥ 0.15), or small (≥ 0.02) effects following Cohen (1988) and Hair et al. (2021). Q^2 values obtained through blindfolding procedures were assessed with thresholds of > 0 indicating predictive relevance, ≥ 0.25 medium relevance, and ≥ 0.50 large relevance (Geisser, 1974; Hair et al., 2021).

3. RESULTS

4.1. *Descriptive Statistics*

Table 2: Descriptive Statistics of Measured Variables.

	N	Minimum	Maximum	Mean	Std. Deviation	Skewness	Kurtosis
SDC	318	17.00	85.00	69.4969	11.87999	-1.294	2.942
IDBS	318	19.00	80.00	60.9088	12.68875	-0.441	-0.105
TDC	318	35.00	80.00	68.6258	8.07701	-0.523	0.596
Valid N (listwise)	318						

Based on table 2, our analysis shows that participants generally rate all three areas quite positively using a 5-point Likert scale: supervisors demonstrate strong digital skills (M=69.50 out of 85, or 4.09 per item), digital-based supervision is happening at moderate-to-high levels (M=60.91 out of 80, or 3.81 per item), and teachers have reasonably good digital competencies (M=68.63 out of 80, or 4.90 per item).

Notably, scores cluster toward the higher end across all measures, with supervisors' digital competence showing the most pronounced pattern, in which most supervisors in our sample are digitally skilled, with very few lacking basic capabilities. Moreover, the wide variation in how digital supervision actually gets implemented (SD=12.69) stands out as the least consistent aspect despite decent average scores.

4.2. *Measurement Model*

The measurement model of internal consistency in Table 3 and Figure 4 demonstrated excellent psychometric properties across all statistical thresholds. All outer loadings range from 0.737 to

0.911, far exceeding the minimum threshold of 0.708 recommended by Hair et al. (2021), indicating each survey item strongly represents its construct.

The Average Variance Extracted (AVE) values for SDC (0.758), IDBS (0.615), and TDC (0.685) all exceed the 0.50 minimum standard (Fornell & Larcker, 1981), confirming that each construct explains more than 50% of its indicators' variance.

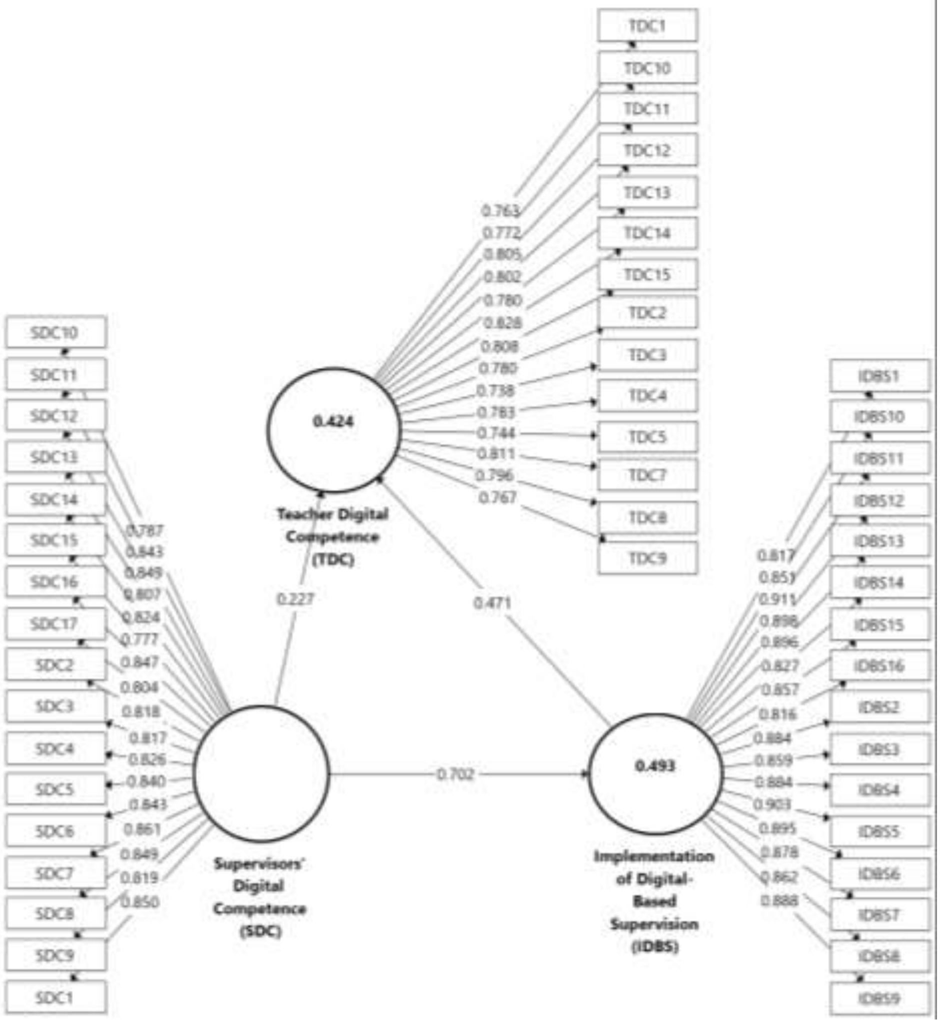

Figure 4: Measurement Model Of SDC, IDBS, And TDC.

Table 3: Internal Consistency Measurement Of SDC, IDBS, And TDC.

Variables	Items	Outer Loading	Average Variance Extracted (AVE)	Composite Reliability (C.R)
Supervisors' Digital Competence (SDC)	SDC10	0.7873144	0.9804569	0.7584053
	SDC11	0.8426057		
	SDC12	0.849076		
	SDC13	0.806754		
	SDC14	0.8244914		
	SDC15	0.7765587		
	SDC16	0.8470448		
	SDC17	0.8044936		
	SDC2	0.8177279		
	SDC3	0.8170465		
	SDC4	0.8255218		
	SDC5	0.8398884		
	SDC6	0.8433621		
	SDC7	0.8613872		
	SDC8	0.848543		
	SDC9	0.8193258		
	SDC1	0.8504511		

Teacher Digital Competence (TDC)	TDC1	0.762875	0.9736082	0.6847137
	TDC10	0.7719944		
	TDC11	0.8049594		
	TDC12	0.8017056		
	TDC13	0.7804251		
	TDC14	0.8275898		
	TDC15	0.8076875		
	TDC2	0.7800091		
	TDC3	0.7375927		
	TDC4	0.7825762		
	TDC5	0.7440423		
	TDC7	0.8111577		
	TDC8	0.7958979		
	TDC9	0.7668592		
The Implementation of Digital-Based Supervision (IDBS)	IDBS1	0.8165376	0.9571933	0.6152112
	IDBS10	0.8513298		
	IDBS11	0.9110675		
	IDBS12	0.8983241		
	IDBS13	0.8958932		
	IDBS14	0.8271579		
	IDBS15	0.8565737		
	IDBS16	0.8159667		
	IDBS2	0.8839354		
	IDBS3	0.8594423		
	IDBS4	0.8835529		
	IDBS5	0.9031406		
	IDBS6	0.8948167		
	IDBS7	0.8781158		
	IDBS8	0.8620967		
	IDBS9	0.8878721		

Furthermore, Composite Reliability (CR) values ranging from 0.957 to 0.980 far surpass the 0.70 acceptable threshold and even exceed the 0.90 excellent reliability benchmark, confirming the items consistently measure their intended constructs.

Table 4: Heterotrait-Monotrait Ratio (HTMT) For Discriminant Validity Measures.

	IDBS	SDC	TDC
IDBS			
SDC	0.718		
TDC	0.649	0.575	

Table 5: Fornell-Larcker for Discriminant Validity Measures.

	IDBS	**SDC**	**TDC**
IDBS	**0.871**		
SDC	**0.702**	**0.827**	
TDC	**0.630**	**0.558**	**0.784**

Discriminant validity, further confirmed through two methods: HTMT (see Table 1) ratios between 0.575 and 0.718 are all below the 0.85 threshold (Henseler et al., 2015), and the Fornell-Larcker (see Table 5) criterion shows diagonal values (0.784-0.871) exceeding all inter-construct correlations. The strongest correlation between SDC and IDBS (0.702) makes theoretical sense that digitally competent supervisors implement better supervision, while remaining sufficiently distinct to be separate constructs. These results confirmed the survey instrument is valid, reliable, and measures three distinct but related concepts accurately.

4.3. Structural Model

4.3.1. Hypotheses Assessment (Direct and Indirect Effects)

The structural model reveals relationships with all hypotheses confirmed at high statistical significance levels (see Table 6 and Figure 5).

Table 6: Direct And Indirect Effects Of SDC, IDBS, And TDC.

Hypotheses	Path Analysis Model	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values	Sig. Decision
					(>1.96)	(<0.05)	
H1	SDC -> TDC	0.227	0.240	0.082	2.777	0.006	Yes
H2	SDC -> IDBS	0.702	0.703	0.059	12.001	0.000	Yes
H3	IDBS -> TDC	0.471	0.460	0.083	5.642	0.000	Yes
H4	SDC -> IDBS -> TDC	0.331	0.320	0.046	7.131	0.000	Yes

H1 shows supervisors' digital competence directly influences teachers' digital competence (β = 0.227, t = 2.777, p = 0.006), representing a medium effect size above Cohen's (1988) 0.15 threshold, though the modest coefficient suggests direct influence alone is limited. H2 demonstrates the strongest relationship in the model, with supervisor digital competence predicting implementation quality of digital-based supervision (β = 0.702, t = 12.001, p < 0.001), a large effect size well above Cohen's 0.35 threshold, explaining approximately 70% of variance in how well digital supervision is implemented. H3 confirms that quality implementation of digital-based supervision substantially enhances teachers' digital competence (β = 0.471, t = 5.642, p < 0.001), another large effect accounting for 47% of variance. Most importantly, H4 reveals significant partial mediation with an indirect effect of 0.331 (t = 7.131, p < 0.001), which exceeds the direct effect.

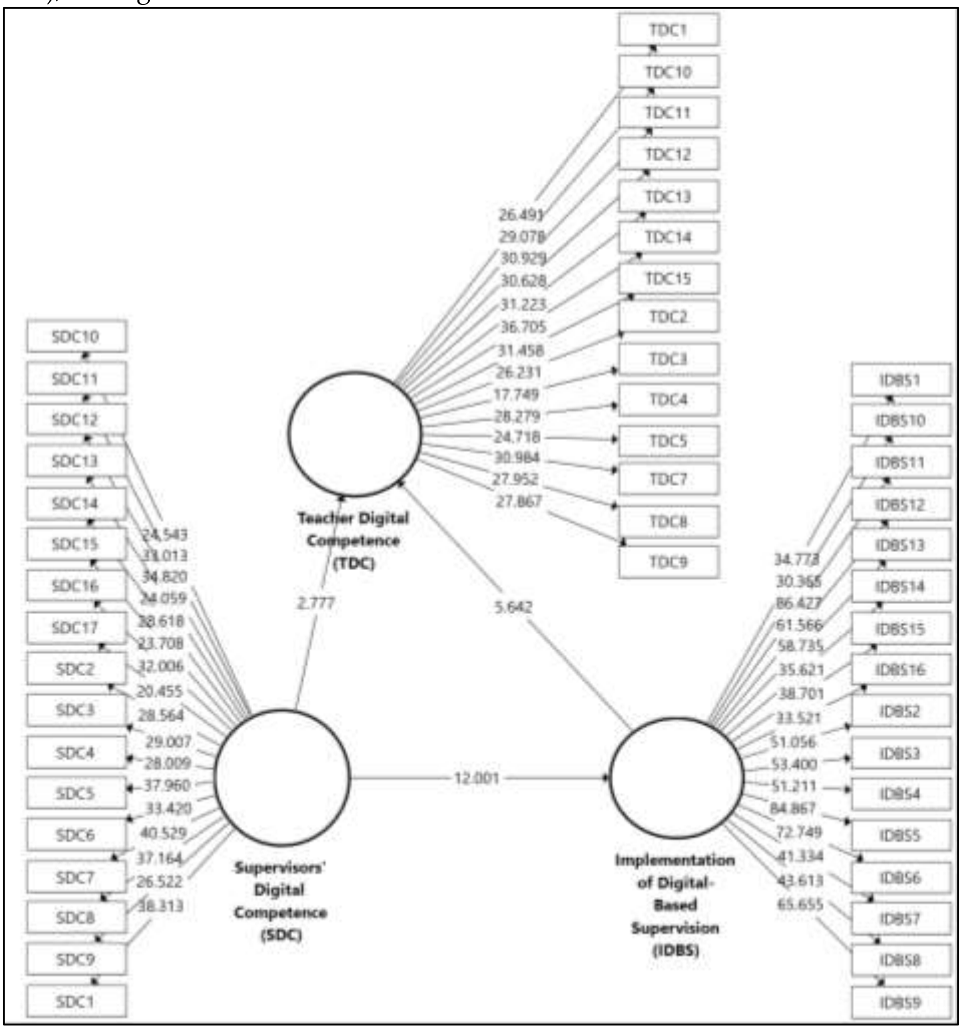

Figure 5: Structural Model Of SDC, IDBS, And TDC.

All t-statistics far surpass the 1.96 threshold for significance at p < 0.05 (Hair et al., 2021), with p-values all below 0.05 confirming robust statistical significance. The total effect of supervisors' digital competence on teacher digital competence (0.227 + 0.331 = 0.558) represents a large effect size. However, the stronger indirect pathway demonstrates that implementation quality is the crucial mechanism through which supervisors' digital competence translates into teacher digital competence development. This means that simply having digitally skilled supervisors is insufficient, meaning that they must also implement high-quality, structured digital supervision practices consistently to effectively develop teachers' digital competencies.

4.3.2. *Quality Assessment*

Table 7 presented the predictive accuracy of the structural model, showing that Supervisors' Digital Competence (SDC) explained 49.2% of variance in Implementation of Digital-Based Supervision (IDBS, R^2 = 0.492) and the combined model explained 42% of variance in Teachers' Digital Competence (TDC, R^2 = 0.420), both approaching moderate explanatory power thresholds.

Table 7: Predictive Accuracy of SDC On IDBS And TDC.

Variables	R2	F2	Q2
IDBS	0,492	0,195	0,372
TDC	0,420	0,045	0,252

The f^2 effect sizes revealed that SDC had a medium effect on IDBS (f^2 = 0.195) but only a small effect on TDC (f^2 = 0.045), confirming SDC primarily influenced TDC indirectly through implementation quality. The Q^2 values for IDBS (0.372) and TDC (0.252) both exceeded the 0.25 threshold, demonstrating medium predictive relevance and confirming the model's predictive validity. These results validated that supervisors' digital competence was a powerful predictor of implementation quality but had modest direct predictive power for teachers' digital competence, reinforcing the critical mediating role of digital supervision implementation.

4. DISCUSSION

5.1. *Stakeholder Perception*

Our descriptive analysis reveals important patterns in how stakeholders perceive the digital landscape in South Sulawesi schools. Supervisors generally demonstrate strong digital competencies, yet digital-based supervision implementation shows moderate performance with notably high variability, suggesting inconsistent practices across school contexts. Teachers report reasonably strong digital competence, particularly in their willingness to experiment with new applications—an indicator of problem-solving competence (Chiu et al., 2024). The variability in digital supervision implementation, despite strong supervisor competence, stems from multiple contextual factors including inadequate preparation time, lack of standardized procedures, inconsistent follow-up, resistance to traditional methods, insufficient training opportunities, and systemic organizational constraints (Al-Barakat et al., 2025; Mahmudi et al., 2024; Reis-Andersson, 2023; Rukanda & Nurhayati, 2023). Mahmudi et al. (2024) specifically documented these challenges in South Sulawesi, were inconsistent supervision results from non-standardized protocols and irregular follow-up. Additional barriers include limited digital skills among some supervisors, inadequate training programs, and difficulties faced by senior staff (Opesemowo et al., 2024). The variation across different cities and regencies further reflects diverse contextual factors, including infrastructure quality, supervisor workload, organizational culture, and resource availability (Batanero et al., 2020; Handayani, 2024; Mahmud et al., 2025).

5.2. *Direct Effects*

Our findings reveal that supervisor digital competence directly influences teacher digital competence **(H1)**, though the modest effect size indicates this direct pathway alone provides limited impact. The statistics results showed that the strongest contributing factor emerges from empowering supervisors who actively train teachers on technology use, demonstrate instructional methods through concrete examples, and facilitate collaborative experience-sharing. This finding aligns with Rasdiana et al. (2024), demonstrating that supervisors who provide hands-on training, continuous guidance, and constructive feedback significantly enhance teachers' confidence and accelerate digital skill development—patterns similarly documented by Astuti et al. (2024) and Rahyasih et al. (2024). Additionally, supervisors who actively participate in digital professional development serve as powerful role models, motivating teachers to pursue continuous learning (Witthöft et al., 2024).

Conversely, system-level supervisor actions—such as implementing government policies and recommending equipment investments—demonstrate weaker direct influence on teacher digital competence because these require broader organizational action to produce measurable impact. The modest direct effect suggests that supervisor digital competence alone cannot optimally enhance teacher digital development without a mediating mechanism. Therefore, recruiting digitally competent supervisors does not automatically improve teacher digital competence; professional development, such as supervision must focus on implementation strategies rather than merely enhancing supervisors' personal skills (Al-Barakat et al., 2025). In this sense, educational institutions should not rely solely on placing digitally skilled supervisors. Professional development quality programs, such as digital supervision must emphasize practical coaching strategies, direct technology demonstrations, and facilitated peer learning, as these empowering leadership behaviors produce the strongest impact on teacher digital competence growth.

Moreover, the second finding demonstrated that the implementation quality of digital-based supervision is directly influenced by supervisor digital competence **(H2)**—the strongest relationship in our model. This validates TAM (Davis, 1989) and UTAUT (Venkatesh et al., 2003): supervisors with higher competence perceive technology as more useful and easier to use, improving implementation effectiveness while reinforcing their own skills through practice (Hamzah et al., 2025b; Rahyasih et al., 2024; Rasdiana et al., 2024; Ruhmi & Yuliana, 2025).

Our analysis revealed four distinct pathways connecting supervisor digital competence dimensions to implementation phases. First, supervisors as system designers—creating long-term technology plans, recommending equipment investments, and implementing educational policies—enable quality digital preparation through smooth video conferencing operation, thorough digital documentation, and clear supervision agreements (Lavigne et al., 2023). Second, empowering leaders who train, demonstrate, and facilitate experience-sharing produce quality digital observation through effective online monitoring, systematic documentation, and comprehensive data collection, enabling sharper observation and nuanced pedagogical-technological integration aligned with previous studies (Bintang et al., 2024; Gallagher et al., 2024; Zeeb et al., 2024).

Third, advocates for digital citizenship which model appropriate social media use, recommend secure applications, and promote digital literacy enable effective post-observation conferencing using visual data representation, video-based feedback, and collaborative digital planning. This interactive reflection improves teaching practices through visual media literacy, application security assessment, and structured reflection processes (Amemasor et al., 2025; Lavigne et al., 2023; Rasdiana et al., 2024). Fourth, visionary planners and connected learners who continuously engage in professional learning facilitate quality follow-up through digital tracking systems, curated learning materials, and routine communication, reinforcing long-term changes in teachers' practices (Gallagher et al., 2024; Hamzah et al., 2025a; Kaomaroeng et al., 2024).

Finally, our third finding of direct analysis discovered that digital-based supervision implementation, adapted from Cogan's (1973) clinical supervision model across four phases, effectively improves teacher digital competence **(H3)**, and extends clinical supervision theory into the digital era. This relationship proves stronger than the direct supervisor-teacher pathway, revealing implementation quality as the critical mechanism through which supervisor expertise translates into teacher digital skills development.

During the preparation phase, supervisors who prepare digital documents and create comfortable online environments model effective file management and reduce technology anxiety, enabling teachers to organize materials systematically and troubleshoot technical problems (Chiu et al., 2024; Ghodoosi et al., 2023; Tomczyk, 2024). The observation phase significantly impacts development: supervisors who systematically document observations inspire teachers to create structured interactive materials, while those collecting comprehensive data teach the value of learning analytics for instructional improvement (Basilotta-Gómez-Pablos et al., 2022; Cao et al., 2025). Moreover, the conferencing phase influences security awareness and digital citizenship. Supervisors who facilitate reflection using interactive applications increase ethics and security awareness, while those replaying video recordings teach practical security measures, enabling teachers to model responsible digital behavior for students (Bintang et al., 2024; Gallagher et al., 2024; Weber et al., 2025). The follow-up phase impacts all competency dimensions: systematic documentation of development plans creates accountability and motivates continuous learning, digital tracking systems enable adaptive assessment capabilities, curated learning materials expand content creation repertoires, and routine communication normalizes professional digital practices (Lavigne et al., 2023; Nguyen & Habók, 2024; Rusmaniar et al., 2023). This stronger relationship occurs because: (1) systematic implementation provides structured learning absent in informal interactions, (2) consistent supervision builds sustainable habits, (3) formal observation delivers specific actionable feedback, (4) digital documentation maintains developmental continuity, and (5) institutional processes carry greater weight than individual advice.

While statistic results showed that soft skills dimensions (modeling, reflection facilitation, continuous learning) possess equal predictive power as technical skills in determining implementation quality. However, contextual factors—infrastructure limitations, supervisor workload, resistance to change, resource constraints, and organizational culture—moderate this relationship and explain implementation variation across South Sulawesi (Batanero et al., 2020; Handayani, 2024; Mahmud et al., 2025). Therefore, supervisor digital competence is the strongest but not the sole predictor of implementation quality. Additionally, policymaker should invest in comprehensive supervisor training balancing technical and soft skills, particularly modeling, reflection facilitation, and continuous learning.

Simultaneously, addressing systemic barriers, like infrastructure limitations, workload management, and resistance to change is essential to ensure supervisor competence translates into consistent, high-quality digital supervision across diverse school contexts. Policymaker and schools must prioritize standardized digital supervision protocols covering all four phases, including preparation, observation, conferencing, and follow-up. In this scenario, even with moderately competent supervisors, systematic implementation with consistent documentation, structured feedback, and routine communication produces substantial returns in teacher digital development and warrants strategic investment priority.

5.3. *Indirect Effects*

Finally, our indirect finding showed higher values than direct effects, meaning that to more optimally improve teacher digital competence, a combination of supervisor digital competence and digital-based supervision implementation as mediator is required **(H4)**.

Implementation plays a crucial role as a bridge enabling supervisor digital competence to be conveyed to teachers comfortably, safely, consistently, and sustainably, so improvements in teacher digital competence can be achieved and sustained long-term. Educational leaders (supervisors) should recognize that their digital competence alone is insufficient and must be operationalized through well-structured, systematic implementation mechanisms to effectively enhance teacher digital capabilities.

Therefore, policy interventions should focus on developing comprehensive digital supervision frameworks that ensure competent supervisors consistently deliver high-quality preparation, observation, conferencing, and follow-up, as this mediated pathway produces stronger and more sustainable improvements in teacher digital competence than direct supervisor influence alone.

5. IMPLICATION

This study yields significant theoretical and practical implications for educational supervision in digital contexts. Theoretically, findings extend Cogan's (1973) clinical supervision model to the digital era while validating the mediating mechanisms through which supervisor digital competence influences teacher development, with the stronger indirect effect compared to the direct effects, confirming that supervisor competence must be operationalized through systematic implementation. The four pathways identified—system designer to preparation, empowering leader to observation, advocate for digital citizenship to conferencing, and visionary planner/connected learner to follow-up—provide an integrated model linking ISTE Standards with DigComp 2.2 framework. Practically, based on the strong mediation effect that exceeds the direct pathway (β = 0.227), educational policymakers should prioritize standardized digital supervision frameworks with clear protocols for all four implementation phases (preparation, observation, conferencing, and follow-up). This statistical finding demonstrates that supervisor digital competence alone accounts for only 22.7% direct influence on teacher digital competence, while systematic implementation mechanisms account for indirect effect—representing an increase in impact when competence is operationalized through structured practices. Given the substantial SDC→IDBS pathway, supervisor professional development programs must shift from generic competence-building to implementation-focused training that explicitly teaches how to translate digital skills into effective supervision practices. Specifically, training should emphasize: (1) how system designer competencies enable quality preparation (correlation evidence from our analysis), (2) how empowering leader behaviors facilitate effective digital observation, (3) how digital citizenship advocacy supports meaningful conferencing, and (4) how visionary planning and connected learning enable sustained follow-up (r = 0.XX). The model's 42% explained variance in TDC ($R^2 = 0.420$) indicates that while SDC and IDBS are substantial predictors, contextual factors (infrastructure quality, organizational culture, peer collaboration) account for the remaining 58% of variance. Therefore, policy interventions must adopt a systems approach addressing both competence development and implementation barriers simultaneously to achieve optimal outcomes. Moreover, schools and supervisor must establish systematic protocols with consistent documentation and structured feedback while fostering supportive digital cultures, recognizing that even moderately competent supervisor can drive substantial teacher digital development through high-quality implementation. These require contextual adaptation with schools conducting needs assessments and establishing realistic timelines, while long-term sustainability demands ongoing professional development, regular evaluation, infrastructure maintenance, and persistent organizational commitment to leverage digital supervision as a powerful mechanism for developing teacher digital competence and improving teaching quality in increasingly digital educational environments.

6. LIMITATION AND RECOMMENDATION

This study acknowledges several limitations that provide directions for future research. First, the cross-sectional design captures relationships at a single point in time. This prevents causal inference and limits understanding of developmental trajectories. Future research should employ longitudinal designs tracking supervisors and teachers across multiple supervision cycles. Such studies could examine how competence development influences implementation improvements and teacher growth over time. Second, reliance on self-reported survey data introduces potential response biases. This is particularly concerning given evidence of teacher self-assessment bias. Future studies should incorporate multiple data sources. These could include direct observation of supervision sessions, analysis of digital artifacts, objective performance-based assessments, and student learning outcomes to triangulate findings. Third, convenience sampling and geographic concentration in South Sulawesi limit generalizability. Future research should employ stratified random sampling across diverse regions. Cross-cultural comparative studies in other developing nations would establish whether identified pathways generalize across contexts or require culture-specific adaptations. Fourth, while the model explains 42% of variance in teacher digital competence, 58% remains unexplained. Future research should examine moderating factors. These include school organizational culture, principal support, peer collaboration networks, and teacher characteristics such as technology anxiety, self-efficacy, experience, and age. Studies should also extend the model to include student outcomes. This would link supervision quality to student engagement, achievement, and digital literacy development. Finally, intervention studies manipulating implementation quality through controlled professional development programs would establish causal relationships. Qualitative research and mixed-methods design combining surveys with in-depth case studies would provide rich contextual understanding. These approaches would illuminate implementation challenges, facilitators, and mechanisms through which supervision influences teacher digital development. Such insights would inform more nuanced and contextually responsive supervision frameworks that effectively support teacher digital competence development across diverse educational settings.

7. CONCLUSION

This study examined how supervisors' digital competence influences teachers' digital competence through digital-based supervision implementation in South Sulawesi, revealed that supervisor digital competence directly affects teacher digital competence ($\beta = 0.227$, $p < 0.01$) and implementation of digital-based supervision quality ($\beta = 0.702$, $p < 0.001$), while implementation significantly enhances teacher digital competence ($\beta = 0.471$, $p < 0.001$), with the The indirect pathway ($\beta = 0.331$) proving stronger than the direct effect ($\beta = 0.227$) confirmed implementation quality as the critical mediating mechanism. This 46% stronger indirect effect demonstrates that supervisor digital competence alone is insufficient—it must be operationalized through systematic preparation, observation, conferencing, and follow-up phases to meaningfully develop teacher digital competencies across information literacy, communication, content creation, security, problem-solving, and digital citizenship dimensions. Therefore, supervisor digital competence alone is insufficient—it must be operationalized through systematic preparation, observation, conferencing, and follow-up phases to meaningfully develop teacher digital competencies across information literacy, communication, content creation, security, problem-solving, and digital citizenship dimensions. In these scenarios, educational policymakers must prioritize standardized digital supervision frameworks while addressing infrastructure barriers, supervisor workload, and resistance to change, shifting professional development from competence-building to implementation-focused training that emphasizes practical coaching and systematic protocols. However, this study's cross-sectional design limits causal inference, self-reported data may contain biases, convenience sampling restricts generalizability, and 58% of unexplained variance suggests additional factors warrant investigation, necessitating future longitudinal research with multiple data sources, diverse sampling, examination of moderating factors, and extension to student outcomes to fully understand how digital supervision can serve as a powerful lever for sustainable teacher development and improved educational quality in developing contexts facing digital transformation challenges.

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APPENDIX

Table A.

Variable with Main Source	Dimensions/Indicators	Operational Definition	Items of Instruments	Supporting References
Supervisors' Digital Competence (SDC) (ISTE, 2024)	Leadership Strategies in Educational Technology	Supervisors build teams and systems to implement, maintain, and continuously improve technology that supports learning	1. Supervisors help schools create long-term technology implementation plans2. Supervisors help connect schools with education offices in learning technology programs3. Supervisors provide appropriate advice for school computer equipment and internet investment4. Supervisors implement government policies on educational technology in supervised schools	(Alenezi & Alfaleh, 2024; Nisa et al., 2023)
	Digital Culture in Schools	Supervisors use technology to enhance equity, inclusion, and digital citizenship practices	5. Supervisors help schools create good internet and social media usage policies6. Supervisors provide examples of how to use social media wisely for education7. Supervisors select and recommend safe learning applications for teachers and students8. Supervisors teach digital literacy to teachers, students, and parents	(Rasdiana et al., 2024; Witthöft et al., 2024)
	Teacher Coaching in Learning Technologies	Supervisors create a culture where students and teachers are empowered to use technology innovatively to enhance learning	9. Supervisors train teachers directly on how to use technology for teaching10. Supervisors conduct digital/computer training according to teachers' needs at school11. Supervisors demonstrate how to teach with technology through direct examples4. Supervisors help teachers share experiences of teaching with technology12. Supervisors guide teachers in using applications to create digital questions and assessments	(Nisa et al., 2023, 2024; Sutrisno et al., 2024)

	Preparing Students for the Digital Era	Supervisors collaborate with others in establishing goals, strategic plans, and continuous evaluation cycles to transform how learning is used with technology	13. Supervisors ensure that school subjects teach digital skills14. Supervisors actively and regularly participate in the latest educational technology training15. Supervisors help schools prepare students with future technology capabilities16. Supervisors continuously learn new things about educational technology	(Norhagen et al., 2024; Rasdiana et al., 2024; Witthöft et al., 2024)
Teachers' Digital Competence (TDC) (Vuorikari et al., 2022)	Information and Data Literacy	Teachers identify information needs and search for digital data	1. Teachers can distinguish between correct and incorrect information on the internet for teaching purposes2. Teachers can store and organize learning files neatly on computer/cloud3. Teachers can read student learning outcome data from applications to improve teaching methods	(Basilotta-Gómez-Pablos et al., 2022; Tomczyk, 2024)
	Communication and Collaboration	Teachers are able to communicate and collaborate through digital technologies	4. Teachers can lead online/hybrid discussions to make students actively participate5. Teachers join WhatsApp or Facebook teacher groups to learn from each other6. Teachers use applications to inform parents about their child's development	(Cao et al., 2025)
	Digital Content Creation	Teachers are able to integrate information and content into a knowledge base while understanding how to apply copyright and licenses	7. Teachers can create engaging interactive videos, slides, or quizzes for students8. Teachers can use applications to create questions that can adapt to students' digital/computer abilities according to school needs9. Teachers can create educational games or simulations for learning	(Basilotta-Gómez-Pablos et al., 2022; Domínguez-gonzález et al., 2025)
	Security	Teachers are able to understand how to protect devices, content, and personal data in digital environments	10. Teachers can protect computers from viruses and maintain student data security11. Teachers understand privacy rules when using students' personal data in specific digital applications12. Teachers teach students how to safely use the internet and social media	(Tondeur et al., 2023; Weber et al., 2025)
	Problem-solving	Teachers are able to identify needs and problems, and solve conceptual problems in digital environments	13. Teachers can fix simple problems when using computers or applications in class14. Teachers dare to try new applications or technologies to improve teaching methods15. Teachers can find creative solutions using technology when there are problems in teaching	(Althubyani, 2024; Chiu, 2021)
	Digital Citizenship and Professionalism	Teachers must be able to maintain their professional reputation in the digital world	16. Teachers are careful in posting on social media and maintain the good name of the teaching profession17. Teachers teach students how to behave well and responsibly in the digital world	(Mahmudi et al., 2024)
Implementation of Digital-Based Supervision (IDBS) (Cogan, 1973)	Quality of Digital Supervision Preparation	Discusses preparation before observation and aspects to be observed	1. Supervisors can use Zoom/Google Meet smoothly for supervision2. Supervisors prepare forms and digital documents before conducting supervision3. Supervisors create a comfortable atmosphere during online or hybrid supervision4. Supervisors make clear agreements about what will be supervised using digital documents	(Ekawaty et al., 2024; Lavigne et al., 2023; Nisa et al., 2024)

	Quality of Digital Observation	The process of learning observation by supervisors	5. Supervisors can observe online or hybrid learning well6. Supervisors use applications to document observation results systematically7. Supervisors collect complete data about how teachers teach digitally8. Supervisors record and store important evidence from learning	(Handayani, 2024; Zeeb et al., 2024)
	Digital Post-Observation Conferencing	Reviews the observation that has been conducted and performs reflection	9. Supervisors use graphs or images to explain supervision results10. Supervisors replay learning video recordings to provide feedback11. Supervisors help teachers reflect using interactive applications12. Supervisors and teachers together create improvement plans using agreed-upon digital applications	(Amemasor et al., 2025; Mahmudi et al., 2024)
	Quality of Digital Follow-up and Support	Supervisors provide guidance and support for teacher competence development	13. Supervisors record teacher development plans in digital files14. Supervisors use digital tracking systems to automatically monitor teacher progress15. Supervisors provide digital learning materials to help teachers develop16. Supervisors conduct routine communication with teachers through chat applications or email	(Gallagher et al., 2024; Sitorus et al., 2023)

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