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SUPERVISORS' DIGITAL COMPETENCE AND DIGITAL-BASED SUPERVISION IMPLEMENTATION: A HIGHER-ORDER CONSTRUCT ANALYSIS IN SENIOR HIGH SCHOOLS

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ABSTRACT

Although digital supervision has been extensively examined at a conceptual level, empirical evidence directly linking supervisors' digital competence to the quality of digital-based supervision implementation in the Indonesian context remains scarce. This study investigates the influence of Supervisors' Digital Competence (SDC) on Digital-Based Supervision Implementation (DBSI) in senior high schools in South Sulawesi Province, Indonesia. SDC was operationalized as a reflective-formative higher-order construct comprising four dimensions: Technology Leadership Strategy (TLS), School Digital Culture (SDCu), Teacher Technology Coaching (TTC), and Student Digital Preparation Focus (SDPF). DBSI was measured across four dimensions adapted from Cogan's (1973) clinical supervision model: Digital Supervision Preparation Quality (DSPQ), Digital Observation Quality (DOQ), Digital Post-Observation Conference (DPOC), and Digital Follow-Up and Support Quality (DFSQ). A quantitative approach with a cross-sectional survey design was employed, involving 318 respondents (teachers, principals, vice-principals) from 78 schools across 17 districts/cities. Data were analyzed using Partial Least Squares Structural Equation Modeling (PLS-SEM) via SmartPLS 3.0, applying the disjoint two-stage approach for HOC estimation. Results indicated that SDC exerted a positive and significant effect on DBSI ($\beta = 0.708$; $t = 11.962$; $p < 0.001$), with $R^2 = 0.499$ and effect size $f^2 = 1.003$ (large). The SDPF dimension contributed the highest formative weight (outer weight = 0.481), followed by TLS, TTC, and SDCu. These findings confirmed that supervisors' digital competence is the primary predictor of successful digital-based supervision, with important policy implications for the professional development of educational supervisors in the digital age.

KEYWORDS: Supervisors' Digital Competence, Digital-Based Supervision, Higher-Order Construct, PLS-SEM, Disjoint Two-Stage.

1. INTRODUCTION

The growing integration of digital technology into educational governance has fundamentally altered the demands placed on school supervisors. At the heart of this transformation lies a critical but underexplored variable: supervisors' digital competence. This study takes the position that digital competence is not merely a supplementary skill for supervisors, but rather the primary driver of whether digital-based supervision can be implemented effectively in schools. In today's rapidly evolving digital education landscape, the digital competence of school supervisors represents a key factor in effective educational oversight and instructional monitoring (Mahmud et al., 2025). In this context, digital competence encompasses the knowledge, skills, and attitudes that enable supervisors to leverage digital technology effectively in supervisory activities, instructional monitoring, and data-driven decision-making, including the use of online platforms for observation, feedback, and professional collaboration (Astuti et al., 2024). Empirical studies have indicated that supervisors with strong digital competence are more effective in supporting teachers to improve instructional performance and innovation, owing to their capacity to bridge the gap between digital competence theory and digital-based supervision practice (Mahmud et al., 2025; Rusmaniar et al., 2023).

According to Davis (1989), the Technology Acceptance Model (TAM) posits that supervisors with strong competence are better prepared and more capable of integrating technology into their supervisory practice. This, in turn, supports the implementation of digital-based supervision while enabling them to provide more effective guidance to teachers in developing their digital competence. Consistent with TAM, the Unified Theory of Acceptance and Use of Technology (UTAUT) by Venkatesh et al. (2003) identifies factors that influence an individual's acceptance and use of technology. UTAUT explains that four key variables drive behavioral intention and technology use: (1) performance expectancy (the belief that technology helps improve work outcomes); (2) effort expectancy (ease of using technology), (3) social influence (the degree of support or pressure from others), and (4) facilitating conditions (the availability of resources and technical support).

Beyond TAM and UTAUT, this study is also grounded in Rogers (2003) Diffusion of Innovation Theory (DoI). This theory explains how innovations, including digital technology in supervision, spread and are gradually adopted within a social system through specific communication channels. In this study, supervisors with strong digital competence serve as change agents who accelerate the diffusion of digital supervision practices in schools, considering factors such as the technology's relative advantage, compatibility with existing practices, and the complexity of its use (Rogers, 2003). Taken together, these three theories, TAM, UTAUT, and DoI, provide a comprehensive theoretical foundation for understanding how supervisors' digital competence shapes the adoption and implementation of digital-based supervision in schools. Importantly, this study argues that these three frameworks are not merely parallel lenses but mutually reinforcing: TAM explains individual readiness, UTAUT contextualizes the social and organizational conditions that support adoption, and DoI captures the systemic diffusion of digital practices that supervisors catalyze across their school networks.

As mediators between digital policy and practice, supervisors play a strategic role in translating digital education policies into concrete actions at the school level (Sumampow & Tudus, 2024). This role encompasses developing technology-use guidelines, strengthening digital support structures, and aligning supervisory practices with curricular goals and educational quality standards. Contextual literature also highlights that transforming supervisors' roles—from mere administrative overseers to facilitators and leaders of digital change—is essential for accelerating technology integration into modern educational practice (Bintang et al., 2024).

Furthermore, Ruhmi and Yuliana (2025) affirmed that without adequate digital competence, the implementation of digital supervision will be ineffective. Low digital competence among supervisors can hinder optimal use of digital tools, limit their capacity to provide quality feedback, and impede adaptation to changes in educational technology. Other studies by Astuti et al. (2024) and Sapwa et al. (2025) evaluating digital supervision practices in schools confirmed that while technology can expand the reach and efficiency of supervision, its successful implementation depends heavily on supervisors' digital readiness to utilize technology platforms, interpret digital learning data, and facilitate learning processes responsive to twenty-first-century needs.

The implementation of educational supervision in the digital transformation era faces increasingly complex challenges due to the demands of integrating technology into management systems

and instructional development (Ramadhan et al., 2026). The transformation of supervision from conventional to digital models has emerged as a response to advances in information and communication technology, aimed at enhancing efficiency, accountability, and the quality of teacher development (Astuti et al., 2024; Rahmita & Isnaini, 2025). However, field realities reveal that the implementation of digital supervision remains uneven across schools. Case studies in primary schools reveal limitations in digital infrastructure, gaps in teachers' technology competence, and changing communication patterns that affect the effectiveness of supervisory feedback. Furthermore, supervisory practices in some regions remain manual and poorly documented, resulting in suboptimal teacher development processes and difficulty in providing systematic professional feedback (Rufaida et al., 2025).

Another emerging concern is the limited empirical evidence directly linking supervisors' digital competence to actual digital supervision practices in schools. This study contends that this gap is not incidental but structural: the field has prioritized concept-building over measurement, leaving practitioners without evidence-based guidance on which competency dimensions matter most for the quality of supervision. According to Ayuningrum and Atikah (2024), many studies prioritized developing models, strategies, or concepts of digital supervision over empirical testing of relationships among variables. This aligns with Hashim et al. (2022), who argue that many foundational developments in digitalization models, such as those addressing change integration, digital competence, and digital entrepreneurship, still need to be tested through mixed empirical research designs. According to Sulistiobudi et al. (2021), although supervisory competence has been identified as encompassing higher-order thinking skills, social skills, work attitudes, and managerial ability, the literature rarely examines the specific dimensions of digital competence in the context of supervisors' roles as strategic agents of educational transformation. The literature generally addresses digital competence only in relation to school principals. This is consistent with Ghavifekr (2022) and Timotheou et al. (2022), who argue that technology leadership and a digital mindset among school principals are drivers of digital transformation, without distinguishing the role of supervisors as supra-school actors. This conceptual conflation is problematic: supervisors operate at a systemic level that principals do not, and their digital competence therefore carries different and broader implications for the quality of school-wide digital supervision. Given the gaps identified in prior research and the pressing demands of the Indonesian educational context, this study argues that empirically testing the SDC–DBSI relationship is both theoretically necessary and practically urgent. Accordingly, this study aims to analyze supervisors' level of digital competence, assess the degree of digital-based supervision implementation in schools, and examine the extent to which supervisors' digital competence predicts the quality of that implementation.

2. LITERATURE REVIEW

2.1. Digital Supervision in Education

Digital supervision represents an evolution from traditional pedagogical supervision toward technology-based models that enable flexible, collaborative, and data-supported teacher coaching processes (Handayani, 2024). According to Astuti et al. (2024) and Nisa et al. (2023), the use of digital technology in supervision can facilitate supervisory implementation and effectively enhance teacher competence, while simultaneously addressing the constraints of traditional supervision, which is often limited by time and implementation effectiveness.

The concept of digital supervision is also understood as a renewal of instructional supervision practices that integrate online communication media, virtual observation, and digital reflection to enhance the quality of learning processes (Asmarani et al., 2021). Idris et al. (2025) affirmed that the implementation of technology-based academic supervision, with its flexibility in time and place and the enhanced effectiveness of coaching processes, contributes significantly to the development of teachers' professional skills. Furthermore, Nisa et al. (2024) noted that teacher coaching and monitoring are carried out via digital platforms (Zoom/Meet, WhatsApp, LMS, online forms, collaborative documents) to enhance professional competence and ICT integration. LMS is among the most critical digital monitoring tools, as it can manage the entire web-based learning process, facilitate observation of teaching practices, and deliver feedback online (Sungkowo, 2023). Learning Analytics Dashboards (LADs) are also employed in digital supervision to provide snapshots of learning behavior and help identify at-risk students or underperforming teachers (Susnjak et al., 2022). Furthermore, Sapwa et al. (2025) demonstrate that tools such as Google Classroom and Zoom support supervision through real-time feedback, collaboration, and monitoring of

online learning.

Technology-based digital supervision positively contributes to enhancing teachers' professional competence through systematic and continuous coaching (Idris et al., 2025). According to Posangi et al. (2025), digital supervision can strengthen the digital competence of both teachers and supervisors by combining e-supervision, technology leadership, and school digital culture. Despite its positive impact, digital supervision faces several barriers in practice, including weak network connectivity, limited devices, and dependence on internet access (Yu et al., 2022), digital literacy gaps among teachers and supervisors (Posangi et al., 2025), and the development of dashboards or analytics tools requires significant resources and long-term maintenance (Ramaswami et al., 2022; Susnjak et al., 2022).

2.2. Supervisors' Digital Competence

Supervisors' digital competence in education refers to the knowledge, skills, and attitudes required by educational supervisors, including school principals and education supervisors, to effectively lead, support, and evaluate digital transformation in schools (Hamzah et al., 2025a). The digital competence of educational supervisors is a critical factor in the success of educational system digitalization, as they serve as policy directors, managers of technological resources, and facilitators of instructional innovation (Ersoy & Demırer, 2026). Supervisors require not only digital literacy but also digital pedagogical competence, the ability to understand how technology supports learning processes, assessment, and teacher professional development. According to Chaidir et al. (2025), the effectiveness of digital learning is influenced by educators' technology literacy and the implementation of digital curricula, with learning effectiveness serving as a mediator of improved student outcomes. Since supervisors are responsible for evaluating instructional practice, they must assess the appropriateness of technology use in relation to pedagogical objectives, not merely whether digital devices are being used.

Supervisors' digital competencies consist of several indicators adapted from the ISTE Framework, namely 1) advocates for justice and citizenship, 2) visionary planners, 3) empowering leaders, 4) system designers, and 5) connected learners (ISTE, 2024). As digital citizenship advocates, supervisors ensure all school members have equitable access to digital resources, instill ethical practices and data security, and foster a responsible digital culture so technology neither widens inequities nor creates privacy or security risks (Alenezi & Alfaleh, 2024). Visionary supervisors set medium- to long-term digital strategy directions, beginning with integrating technology use with curricular goals and quality improvement, prioritizing high-impact investments, promoting sustained cultural change, and shaping the pace and quality of technology integration by teachers (Witthöft et al., 2024). Empowering supervisors to provide coaching, mentoring, experimentation opportunities, and constructive feedback that build teachers' confidence in experimenting with digital tools, promote lifelong learning, and accelerate the transfer of practical skills. Empirical evidence indicated that structured coaching and mentoring programs led by leaders accelerated teachers' digital skill development (Rasdiana et al., 2024).

Recent studies also confirmed that the Teacher Technology Coaching (TTC) dimension supervisors' efforts to empower teachers to use technology innovatively significantly enhanced teachers' confidence in integrating digital tools in the classroom (Sutrisno et al., 2024). Supervisors who actively train teachers in the use of digital platforms, provide constructive feedback based on digital observation, and facilitate technology-based professional learning communities proved more effective in driving the transformation of instructional practices (Nisa et al., 2023, 2024; Sutrisno et al., 2024). The Student Digital Preparation Focus (SDPF) dimension has also drawn attention in recent literature. Norhagen et al. (2024) emphasized that supervisors bear a strategic responsibility to collaborate in setting goals and establishing continuous evaluation plans, ensuring that the instructional practices they oversee not only enhance teachers' digital competence but also directly contribute to developing students' digital citizenship and technology readiness in the twenty-first-century education era.

Figure 1: International Society for Technology in Education (ISTE) Standards for Education Leaders.

As systems designers, supervisors help design technical infrastructure (LMS, repositories, data policies) and digital supervision procedures (video observation, learning analytics). This function is critical because, without integrated systems, training and supervision efforts fall short of their potential in developing teacher competence (Witthöft et al., 2024). Supervisors as connected learners continuously keep pace with technological developments and serve as models for professional learning. This is important because it sets a positive example, accelerates the adoption of new strategies, and provides teachers with access to external resources (Witthöft et al., 2024).

Research confirms that actively learning leaders positively impact school culture and teachers' readiness to adopt digital innovations. Digitally competent supervisors are better positioned to provide targeted training and support, helping teachers build their own digital skills and adapt to new supervision platforms (Kaomaroeng et al., 2024). Therefore, to ensure sustained innovation in education, educational leaders and supervisors must acquire digital competence. This step enhances supervisors' individual capacity and raises the overall quality of educational institutions (Hamzah et al., 2025b; Riski et al., 2023).

However, these efforts have yet to operate optimally due to supervisors' discomfort with change or a preference for traditional methods, and staff members have shown resistance to adopting new technology (Reis-Andersson, 2023; Rukanda & Nurhayati, 2023). Furthermore, many supervisors do not receive adequate, ongoing training in digital technology and its educational applications. Existing programs may not cover advanced digital skills or practical classroom integration (Al-Barakat et al., 2025; Arina et al., 2025). Supervisors frequently face heavy workloads, leaving them with little time for self-directed learning or participation in professional development activities focused on digital skills (Reis-Andersson, 2023).

Taken as a whole, the literature on SDC reveals a competence that is both multidimensional and strategically consequential. The four dimensions operationalized in this study—TLS, SDCu, TTC, and SDPF—are not arbitrary categories; they represent the distinct roles that supervisors must fulfill to make digital supervision work in practice. Without strategic vision (TLS), there is no direction. Without a shared digital culture (SDCu), there is no environment. Without coaching (TTC), teachers cannot respond productively to digital supervision. Moreover, without a focus on student digital readiness (SDPF), the entire supervisory effort loses its ultimate purpose. This study, therefore, treats SDC not as a generic background variable, but as the active mechanism through which digital-based supervision is shaped and sustained.

2.3. Digital-Based Supervision Implementation in Schools

Digital-based supervision refers to the use of digital technologies such as online platforms, video conferencing, data analytics, and electronic feedback tools to execute, monitor, and support educational supervision processes (Handayani, 2024). This approach combines the principles of conventional supervision with modern technology, enabling real-time collaboration, observation, and feedback between supervisors and educators without spatial or locational constraints (Nisa et al., 2024).

Well-planned supervision preparation can minimize technical obstacles during observation, facilitate agreement on assessment criteria between supervisors and teachers, and optimize the utilization of collected data (Lavigne et al., 2023). Conversely, without thorough preparation, digital observation risks generating technical confusion, ethical concerns, and poorly targeted feedback, making this aspect a critical starting point for optimization in digital supervision. According to Zeeb et al. (2024), digital observation also allows supervisors to revisit critical moments, compare instructional practices over time, and conduct peer reviews or rubric-based analyses, all of which, when conducted with high quality, can yield positive outcomes for teachers in reflecting on their instructional practices.

Both synchronous and asynchronous digital forums enable deeper reflection, documentation of interactions, and the formulation of follow-up plans linked to observation outcomes. Research shows that systematically structured post-observation conferences can improve teaching practices when the feedback provided is evidence-based (Amemasor et al., 2025; Lavigne et al., 2023). Adequate digital support, progress monitoring through analytics, and continued feedback following observation tend to exert a lasting influence on teaching behavior and reinforce the transformation of digital practices (Gallagher et al., 2024).

In practice, digital supervision implementation across many schools remains suboptimal, affected by inadequate preparation, non-standardized observations, unstructured post-observation conferences, and limited or sporadic follow-up. According to Mahmudi et al. (2024), these conditions prevent digital supervision from fully realizing its potential to enhance teachers' digital competence. Additionally, according to Opesemowo et al. (2024), both supervisors and teachers still face limitations in the digital knowledge and skills needed to utilize supervision tools effectively. Senior educators face particular challenges in adopting new technologies, while targeted training programs remain scarce.

Digital supervision implementation is becoming increasingly critical, given the rapid digitalization of education and the need to adapt supervisory practices to support remote and hybrid learning (Sitorus et al., 2023). The adoption of this approach can extend the reach of supervision, particularly for schools in remote or underserved areas, while enabling more flexible scheduling and ongoing support so that teachers in those regions can continue to participate in digital competence development (Nisa et al., 2024). For implementation to proceed optimally, adequate infrastructure support is required, along with digital literacy training, attention to data privacy, and sustained commitment from supervisors and teachers (Handayani, 2024).

Crucially, this review reveals that the quality of DBSI—spanning its four dimensions of DSPQ, DOQ, DPOC, and DFSQ—cannot be evaluated in isolation from the supervisors' competencies who execute it. Poorly prepared supervisors will produce poorly executed digital supervision, regardless of how sophisticated the technology platform may be. This recognition establishes the conceptual link between DBSI and the second core variable of this study: Supervisors' Digital Competence (SDC).

The foregoing review of the literature on DBSI and SDC converges on a single, testable proposition: supervisors with stronger digital competence are better equipped to plan, execute, observe, confer, and follow up on digital supervision—in short, to achieve higher-quality DBSI across all four of its dimensions. This proposition is grounded in the theoretical frameworks of TAM, UTAUT, and DoI and directly addresses the empirical gap identified in the introduction. Based on this synthesis, this study proposes the following hypothesis: Supervisors' Digital Competence (SDC) has a positive and significant effect on Digital-Based Supervision Implementation (DBSI) in senior high schools in South Sulawesi Province, Indonesia.

3. RESEARCH METHOD

3.1. Research Design

This study employed a quantitative approach to address the central research question: How does supervisors' digital competence influence the implementation of digital supervision in schools? A cross-sectional survey design was adopted, collecting all data at a single point in time, as this method is well-suited for analyzing relationships among variables and statistically testing theoretical

assumptions (Demir & Usak, 2025; Hair et al., 2022). For data analysis, Partial Least Squares Structural Equation Modeling (PLS-SEM) was employed, selected for its ability to handle complex variable relationships, strong predictive capacity, and the simultaneous evaluation of measurement and structural models (Afthanorhan, 2013; Cardella et al., 2021). Ultimately, this study tested the proposition that digitally competent supervisors are more likely to deliver high-quality digital-based supervision.

3.2. Participants and Data Collection Procedure

This study involved educational stakeholders who directly participated in or experienced the supervision process at senior high schools in South Sulawesi Province, Indonesia. Participants consisted of principals, vice-principals, and teacher groups who regularly interact with supervisors across a range of activities, including instructional oversight, digital-based supervision, professional development sessions, and technology integration practices. Their ongoing involvement in the supervision process positioned them to provide comprehensive assessments of both Supervisors' Digital Competence (SDC) and Digital-Based Supervision Implementation (DBSI), the two core variables of this study.

Data were collected through a cross-sectional survey conducted between August 4 and September 5, 2025. Prior to the main data collection, a pilot test was carried out at comparable institutions to refine item clarity and ensure the instrument's technical functionality. Following approval from the South Sulawesi Education Office and the administrations of participating schools, the final survey was distributed electronically via Google Forms. A convenience sampling strategy was employed, based on accessibility and willingness to participate, with particular emphasis on schools that had already implemented digital supervision, ensuring that respondents had sufficient firsthand experience with the phenomenon under investigation.

Table 1: Respondent Profile (n = 318)

Category	Group	n	%
Role	Teacher	234	73.58
	Principal	54	16.98
	Vice Principal	30	9.43
Educational Background	Bachelor's Degree (S1)	232	72.96
	Master's Degree (S2)	82	25.79
	Doctoral Degree (S3)	4	1.26
Professional Experience	0–5 years	112	35.22
	6–10 years	78	24.53
	11–15 years	86	27.04
	> 15 years	42	13.21
Supervision on Frequency	Monthly	145	45.60
	Every 2–3 Months	78	24.53
	Semesterly	29	9.12
	Annually	1	0.31
	Irregular	65	20.44
Total		318	100.00

As shown in Table 1, the majority of respondents were teachers (73.58%), followed by principals (16.98%) and vice-principals (9.43%), reflecting the actual proportions of stakeholders who interact directly with supervisors in senior high schools. In terms of educational background, most respondents held bachelor's degrees (72.96%) or master's degrees (25.79%), indicating sufficient academic competence to assess digital supervision practices meaningfully. Regarding professional experience, the relatively even distribution across the 0–5 years (35.22%), 6–10 years (24.53%), and 11–15 years (27.04%) groups reflects a diverse range of perspectives across work experience levels. The most common supervision frequency reported was monthly (45.60%), followed by every 2–3 months (24.53%), suggesting that respondents had sufficient engagement to provide meaningful assessments of both supervisors' digital competence and the implementation of digital-based supervision. Overall, the diversity of respondent

characteristics strengthens the representativeness of the sample in examining the relationship between Supervisors' Digital Competence (SDC) and Digital-Based Supervision Implementation (DBSI).

3.3. Research Instrument

This study used a questionnaire as the primary data collection instrument, carefully designed in accordance with well-established best practices in digital competence assessment and educational research. Prior to the main data collection, the instrument was evaluated through a pilot test to ensure its validity and reliability. All items were measured using a five-point Likert scale ranging from strongly disagree (1) to strongly agree (5), enabling standardized and reliable assessment across all constructs.

The instrument was systematically designed around an interconnected theoretical framework. Supervisors' Digital Competence (SDC) was measured using the ISTE Standards for Education Leaders (ISTE, 2024), adapted into four first-order dimensions that collectively form the HOC of SDC under a reflective-formative specification: (1) Technology Leadership Strategy (TLS) measuring supervisors' capacity to build teams and systems to implement, sustain, and continuously improve technology that supports learning (Alenezi & Alfaleh, 2024; Nisa et al., 2023); (2) School Digital Culture (SDCu) assessing supervisors' role in promoting the use of technology to advance equity, inclusion, and digital citizenship practices in schools (Rasdiana et al., 2024; Witthöft et al., 2024); (3) Teacher Technology Coaching (TTC) measuring supervisors' competence in fostering a culture in which teachers are empowered to use technology innovatively to enhance learning quality (Nisa et al., 2023, 2024; Sutrisno et al., 2024); and (4) Student Digital Preparation Focus (SDPF) evaluating supervisors' capacity to collaborate in setting goals, strategic plans, and ongoing evaluation cycles aimed at transforming how technology is used in the learning process (Norhagen et al., 2024; Rasdiana et al., 2024; Witthöft et al., 2024). Each dimension was operationalized as a reflective first-order construct, with indicators reflecting manifestations of the underlying latent trait. In contrast, the four dimensions collectively form the higher-order SDC construct in a formative manner consistent with the disjoint two-stage reflective-formative HOC approach adopted in this study (Hair et al., 2022; Sarstedt et al., 2019).

Digital-Based Supervision Implementation (DBSI) was operationalized by adapting Cogan's (1973) clinical supervision model into four reflective first-order dimensions, each developed and validated based on recent empirical literature on digital supervision practices (Amemasor et al., 2025; 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 first dimension, Digital Supervision Preparation Quality (DSPQ), measured the extent to which supervisors systematically planned supervision activities using digital tools, encompassing scheduling, goal setting, preparation of digital observation instruments, and communicating expectations to teachers prior to observation (Handayani, 2024; Lavigne et al., 2023). The second, Digital Observation Quality (DOQ), assessed how effectively supervisors conducted structured classroom observations through digital platforms such as video conferencing, screen recording, and learning management systems to document and analyze teaching practices both in real time and asynchronously (Sitorus et al., 2023; Zeeb et al., 2024). The third, Digital Post-Observation Conference (DPOC), measured the quality of structured feedback sessions conducted via digital communication channels following classroom observations, including the delivery of evidence-based feedback, collaborative reflection, and goal-setting for instructional improvement (Amemasor et al., 2025; Lavigne et al., 2023). The fourth, Digital Follow-Up and Support Quality (DFSQ), evaluated the continuity of supervisory support provided through digital means after the conference phase, encompassing progress monitoring, the provision of digital learning resources, and ongoing mentoring via online platforms (Gallagher et al., 2024; Mahmudi et al., 2024; Nisa et al., 2024). Consistent with the SDC measurement model, each DBSI dimension was specified as a reflective first-order construct, and the four dimensions collectively operationalize the DBSI construct. The theoretical integration of the two instruments is grounded in TAM (Davis, 1989), UTAUT (Venkatesh et al., 2003), and Diffusion of Innovations Theory (Rogers, 2003), which together explain how supervisors' digital competence shapes technology acceptance and the overall quality of supervision in schools.

3.4. Data Analysis

This study employed Partial Least Squares Structural Equation Modeling (PLS-SEM) implemented via SmartPLS 3 software to analyze relationships among latent variables. This method was selected for its ability to handle complex measurement models, including Higher-Order

Constructs (HOC), and for its lack of assumptions about multivariate normality in the data (Hair et al., 2022). In this study, the Supervisors' Digital Competence construct was modeled as a Higher-Order Construct with reflective–formative (Type II) specifications. (Ringle et al., 2012; Wetzels et al., 2009). The first-order dimensions Technology Leadership Strategy (TLS), School Digital Culture (SDCu), Teacher Technology Coaching (TTC), and Student Digital Preparation Focus (SDPF) were modeled as reflective constructs, while the HOC was modeled as a formative construct formed by these dimensions. To estimate the HOC model, this study applied the disjoint two-stage approach as recommended by Becker et al. (2012).

In the first stage, each first-order construct was assessed as reflective through evaluation of convergent validity (outer loading ≥ 0.70 and Average Variance Extracted/AVE ≥ 0.50) and reliability using Composite Reliability and Cronbach's Alpha (both ≥ 0.70). Discriminant validity was evaluated using the Fornell–Larcker criterion, whereby the square root of each construct's AVE was compared against its correlations with all other constructs; the square root of AVE must exceed every inter-construct correlation to satisfy this criterion (Fornell & Larcker, 1981; Hair et al., 2022). Once all constructs met the required validity and reliability thresholds, latent variable scores (LVS) were carried forward into the second stage as indicators to construct the HOC formatively. Evaluation of the formative construct involved assessing the significance of outer weights, inspecting Variance Inflation Factor values (VIF ≤ 5) to detect multicollinearity, and testing parameter significance through bootstrapping with 5,000 subsamples — enabling the assessment of path coefficients (β), R^2 values, and effect sizes (f^2) within the hypothesis testing model.

4. RESULTS

4.1. First-Order Construct Assessment.

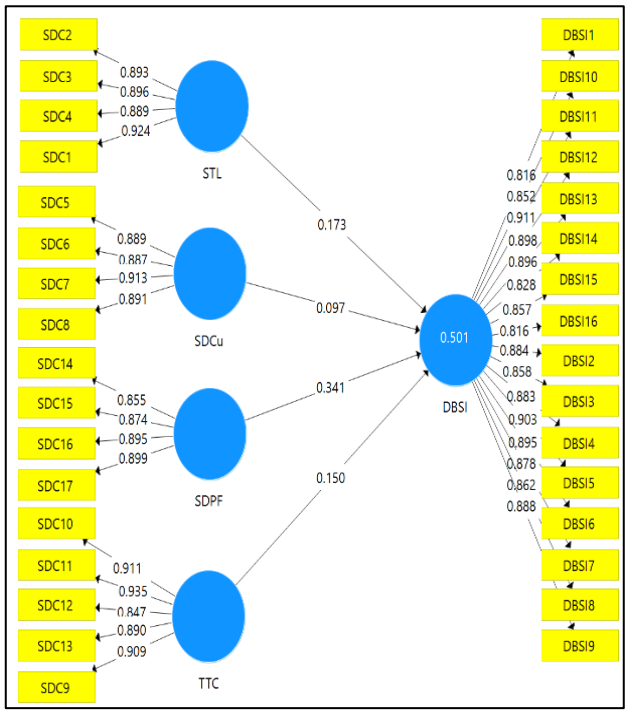

Figure 2: First-Order Model

Table 2 and Figure 2 present the evaluation results of the first-order measurement model for the Supervisors' Digital Competence (SDC) and Digital-Based Supervision Implementation (DBSI) variables. All SDC indicators demonstrated high outer loadings, ranging from 0.847 to 0.935, well above the required threshold of 0.70 (Hair et al., 2022). AVE values across all four SDC dimensions exceeded 0.50 (TLS = 0.811; SDCu = 0.801; TTC = 0.776; SDPF = 0.808), confirming adequate convergent validity. Similarly, Composite Reliability (CR) values for all SDC dimensions surpassed 0.93, indicating excellent internal consistency. For the DBSI variable, all 16 indicators exhibited outer loadings ≥ 0.80, with an AVE of 0.758 and a CR of 0.980, indicating an exceptionally strong measurement instrument. Taken together, these results demonstrate that the first-order measurement model fully satisfies the requirements for convergent validity and reliability, providing a sound basis for proceeding to the higher-order construct (HOC) estimation stage.

Table 2: Internal Consistency Measurement (inner model) SDC and DBSI

Variables	Dimensions	Items	Outer Loading	Average Variance Extracted (AVE)	Composite Reliability (C.R)
Supervisors' Digital Competence (SDC)	TLS	SDC1	0.924	0.811	0.945
		SDC2	0.893		
		SDC3	0.896		
		SDC4	0.889		
	SDCu	SDC5	0.889	0.801	0.942
		SDC6	0.887		
		SDC7	0.913		
		SDC8	0.891		
	TTC	SDC9	0.909	0.776	0.933
		SDC10	0.911		
		SDC11	0.935		
		SDC12	0.847		
		SDC13	0.890		
	SDPF	SDC14	0.855	0.808	0.955
		SDC15	0.874		
		SDC16	0.895		
		SDC17	0.899		
Digital-Based Supervision Implementation (DBSI)		DBSI1	0.816	0.758	0.980
		DBSI2	0.884		
		DBSI3	0.858		
		DBSI4	0.883		
		DBSI5	0.903		
		DBSI6	0.895		
		DBSI7	0.878		
		DBSI8	0.862		
		DBSI9	0.888		
		DBSI10	0.852		
		DBSI11	0.911		
		DBSI12	0.898		
		DBSI13	0.896		
		DBSI14	0.828		
		DBSI15	0.857		
		DBSI16	0.816		

Table 3. Results of Discriminant Validity Testing Using the Fornell–Larcker Criteria

	SDCu	SDPF	DBSI	TTC	TLS
SDCu	0.895				
SDPF	0.817	0.899			
DBSI	0.653	0.629	0.871		
TTC	0.827	0.799	0.680	0.881	
TLS	0.879	0.740	0.644	0.805	0.901

Table 3 presents the discriminant validity results using the Fornell–Larcker criterion, where each construct's square root of AVE (diagonal) is compared against inter-construct correlations (off-diagonal). The square root of AVE values for SDCu (0.895), SDPF (0.899), DBSI (0.871), TTC (0.881), and TLS (0.901) all exceed the highest correlation of each construct with any other. For instance, TLS's square root of AVE (0.901) exceeds its correlations with SDCu (0.879), TTC (0.805), SDPF (0.740), and DBSI (0.644). Similar patterns appear across all constructs, satisfying Fornell & Larcker's (1981) discriminant validity criteria. These results confirm that each construct measures an empirically distinct concept, supporting the instrument's conceptual clarity and measurement quality.

4.2. Higher-Order Construct Assessment (HOC)

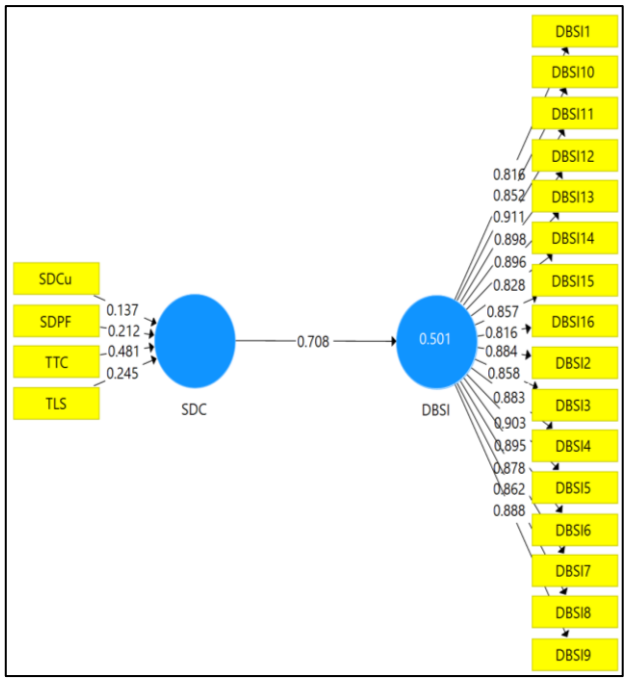

Figure 3: Second-Order Model of the HOC

Table 4: Higher-Order Construct Validity

HOC	LOCs	Outer Weight	T Statistics	P Values	Outer Loadings	VIF
SDC	TLS	0.245	2.154	0.000	0.909	4.794
	SDCu	0.137	0.993	0.000	0.918	4.302
	TTC	0.481	4.220	0.000	0.961	3.525
	SDPF	0.212	1.642	0.000	0.884	4.026

Table 4 presents the higher-order construct (HOC) evaluation results for Supervisors' Digital Competence (SDC), modeled in a formative, two-stage approach. All four dimensions, TLS, SDCu, TTC, and SDPF, were significant at $p < 0.001$,

confirming that each dimension makes a meaningful contribution to forming the SDC construct. SDPF had the highest outer weight (0.481; t = 4.220), followed by TLS (0.245; t = 2.154) and TTC (0.212; t = 1.642), indicating that Student Digital Preparation Focus is the most dominant dimension in shaping supervisors' digital competence. Outer loadings for all dimensions exceeded 0.88, reflecting strong construct relevance even when assessed through formative weights. VIF values for all dimensions were below 5.0 (TLS = 4.794; SDCu = 4.302; TTC = 3.525; SDPF = 4.026), indicating no serious multicollinearity issues among the dimensions (Hair et al., 2022). Overall, these results validate the reflective-formative HOC specification adopted in this study and confirm that the four dimensions collectively and comprehensively represent the Supervisors' Digital Competence construct.

Furthermore, among the outer loading values, the Teacher Technology Coaching (TTC) dimension is the most dominant in representing the Supervisors' Digital Competence construct, with the highest outer loading of 0.961. This indicates that coaching activities and strengthening teachers' technological capacity constitute the most critical aspects of supervisors' digital competence. The remaining dimensions — School Digital Culture (SDCu) (0.918) and Technology Leadership Strategy (TLS) (0.909) — also demonstrate strong contributions. At the same time, Student Digital Preparation Focus (SDPF) yields a comparatively lower outer loading (0.884), though it still reflects an excellent level of construct representation.

4.3. Hypothesis Testing

Table 5: Hypothesis Testing, R^2, and f^2

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
Hypothesis					
SDC -> DBSI	0.708	0.713	0.059	11.962	0.000
R2					
DBSI	0.499	0.510	0.083	6.000	0.000
F2					
SDC -> DBSI	1.003	1.108	0.374	2.680	0.007

Table 5 presents the hypothesis testing results, coefficient of determination (R^2), and effect sizes (f^2) obtained through a bootstrapping procedure with 5,000 subsamples. The results show that Supervisors' Digital Competence (SDC) has a positive and significant effect on Digital-Based Supervision Implementation (DBSI), with a path coefficient of $\beta = 0.708$ ($t = 11.962$; $p = 0.000$), thereby rejecting the null hypothesis (H_0). The R^2 value of 0.499 for DBSI indicates that 49.9% of the variance in digital-based supervision implementation is explained by supervisors' digital competence, which falls within the moderate-to-strong range of predictive power in educational research (Hair et al., 2022). The f^2 value of 1.003 denotes a large effect size ($f^2 > 0.35$) according to Cohen's (1988) classification, signifying that SDC makes a substantively meaningful practical contribution to DBSI. Taken together, these findings provide strong empirical support for the conclusion that enhancing supervisors' digital competence is the primary predictor of successful implementation of digital-based supervision in senior high schools in South Sulawesi.

5. DISCUSSION

This study found that Supervisors' Digital Competence (SDC), comprising four measurable dimensions: Technology Leadership Strategy (TLS), School Digital Culture (SDCu), Teacher Technology Coaching (TTC), and Student Digital Preparation Focus (SDPF), had a positive and significant effect on Digital-Based Supervision Implementation (DBSI), with a path coefficient of $\beta = 0.708$ ($t = 11.962$; $p < 0.001$). This finding empirically validates the theoretical proposition that digitally competent supervisors are better equipped to operate the full cycle of digital-based supervision — spanning Digital Supervision Preparation Quality (DSPQ), Digital Observation Quality (DOQ), Digital Post-Observation Conference (DPOC), and Digital Follow-Up and Support Quality (DFSQ). This aligns with Astuti et al. (2024) and Sapwa et al. (2025), who argue that the success of digital supervision is determined not merely by the availability of technological tools but also by supervisors' holistic mastery of digital competence, encompassing the technical, pedagogical, and ethical dimensions simultaneously. Sumampow and Tudus (2024) further affirm that transforming supervisors' roles in the digital era requires adapting supervisory strategies that are fully integrated with the school's broader digital ecosystem.

The R^2 value for DBSI of 0.499 indicates that supervisors' digital competence explains 49.9% of the variance in the implementation of digital-based supervision. Drawing on Hair et al. (2022) classification, this R^2 value is considered moderate-to-strong and meaningful in the context of educational survey research. In their systematic review of PLS-SEM applications in educational technology research, Demir and Usak (2025) state that R^2 values above 0.40 indicate substantive model

predictiveness, particularly for organizational behavior constructs in schools influenced by multiple contextual factors. The effect size $f^2 = 1.003$ indicates a large effect according to Cohen's (1988) classification, signifying that the inclusion of the SDC variable in the model yields a highly meaningful practical contribution to predicting DBSI. This large f^2 finding is consistent with Mahmud et al. (2025), who identified a strong influence of supervisors' digital competence on learning quality in madrasah settings, and Posangi et al. (2025), who affirm that educational supervision supported by supervisors' ICT competence contributes significantly to overall improvements in educational quality.

Theoretically, these findings can be explained through the three frameworks underpinning this study. First, Davis (1989) Technology Acceptance Model (TAM) argues that supervisors who perceive technology as both useful and easy to use will be better prepared to implement digital-based supervision effectively. Second, Venkatesh et al. (2003) UTAUT clarifies that technology adoption intentions and behaviors are shaped by performance expectancy, effort expectancy, social influence, and facilitating conditions, all four of which are directly reflected in the measurable dimensions of SDC. Third, Rogers (2003) Diffusion of Innovation Theory underscores the role of supervisors as change agents who accelerate the diffusion of digital supervision practices across the schools they oversee. Together, these three theories explain why supervisors' digital competence is not merely a technical prerequisite, but a strategic catalyst that determines the pace and quality of supervision's transformation from conventional to digital-based models (Rasdiana et al., 2024; Witthöft et al., 2024).

The HOC evaluation results further reveal that the Student Digital Preparation Focus (SDPF) dimension recorded the highest outer weight (0.481; $t = 4.220$; $p < 0.001$) among all four dimensions, indicating that it makes the greatest formative contribution to the SDC construct. This finding resonates with Norhagen et al. (2024) argument that supervisors bear a strategic responsibility not only to enhance teachers' digital competence, but also to ensure students' digital readiness through curriculum development and future-oriented learning orientations. In the Indonesian educational context, the role of SDPF is particularly critical given the twenty-first-century digital skill demands that lie at the heart of the Merdeka Belajar policy agenda (Idris et al., 2025). The TLS dimension (0.245; $t = 2.154$) contributes through long-term technology planning connected to the education office ecosystem (Witthöft et al., 2024), while SDCu (0.137) builds a safe and conducive digital environment that serves as a prerequisite for successful digital observation and conferencing (Rasdiana et al., 2024). All VIF values remain below 5.0, confirming that each dimension contributes independently without redundancy (Hair et al., 2022).

The Teacher Technology Coaching (TTC) dimension holds a strategic position as a structural enabler in the digital supervision ecosystem (outer weight = 0.212; outer loading = 0.961). Spanning five items from direct training (TTC1), contextual training (TTC2), technology modeling (TTC3), experience sharing facilitation (TTC4), to digital assessment mentoring (TTC5), TTC builds the foundation of teachers' technical and pedagogical readiness that cannot be bypassed in the digital supervision cycle. Without adequate teacher capacity, the DSPQ, DOQ, DPOC, and DFSQ stages cannot operate effectively, as teachers, the subjects of supervision, lack the readiness to respond productively (Nisa et al., 2023, 2024; Sutrisno et al., 2024). This empirical evidence is reinforced by Gallagher et al. (2024), who describe the characteristics of effective digital technology coaches, and by Asmarani et al. (2021), who affirmed that supervisors serving as direct models of technology use significantly accelerate the adoption of digital innovation among teachers. Kaomaroeng et al. (2024) also found that effective digital supervision models must integrate a coaching dimension grounded in the school's contextual needs, which is consistent with the scope of TTC in this study.

From a practical standpoint, the findings of this study carry important implications for supervisory competence development policy in South Sulawesi and, more broadly, in Indonesia. The combined $R^2 = 0.499$ and $f^2 = 1.003$ indicate that investment in enhancing supervisors' digital competence will yield a significant and measurable impact on the quality of digital-based supervision implementation. Supervisor professional development programs should therefore be systematically designed to address all four SDC dimensions, with particular priority given to SDPF and TTC, the dimensions that demonstrate the highest outer weights and outer loadings, respectively. This is consistent with the recommendations of Al-Barakat et al. (2025) and Arina et al. (2025), who argue that effective digital training programs must cohesively integrate strategic and pedagogical skills, rather than focusing narrowly on technical operational skills. Furthermore, Ramadhan et al. (2026) affirmed that sustainable digital-based supervision transformation requires genuine institutional commitment from the

ministry or regional education offices to provide the necessary infrastructure, continuous training, and monitoring systems that enable supervisors to execute the full digital supervision cycle optimally.

6. CONCLUSION

This study provides empirical evidence that Supervisors' Digital Competence (SDC) had a positive and significant effect on Digital-Based Supervision Implementation (DBSI) in senior high schools in South Sulawesi ($\beta = 0.708$; $p < 0.001$). The R^2 value of 0.499 indicates that SDC accounts for nearly half of the variance in DBSI, while $f^2 = 1.003$ confirms a large and practically meaningful effect size. Higher-order construct (HOC) evaluation results further affirmed that all four SDC dimensions, TLS, SDCu, TTC, and SDPF, collectively and formatively constituted supervisors' digital competence, with SDPF emerging as the highest-contributing dimension (outer weight = 0.481), followed by TLS (0.245), TTC (0.212), and SDCu (0.137). The TTC dimension served as a structural enabler, building teachers' technical and pedagogical readiness as the foundation upon which the entire digital supervision cycle depends. Taken together, these findings affirmed that strategic investment in developing supervisors' digital competence, particularly in the SDPF and TTC dimensions, represents a key intervention for improving the quality of digital-based supervision implementation in schools.

6.1. Limitations

While this study makes a significant empirical contribution, several limitations should be kept in mind when interpreting the findings. First, the cross-sectional design does not permit temporal causal inference; since data were collected at a single point in time, dynamic changes in the relationship between SDC and DBSI could not be captured. Future longitudinal research is needed to validate the stability of this relationship over time. Second, the use of convenience sampling restricted to schools that had already implemented digital supervision means the findings may not fully represent schools that have yet to adopt, or are only beginning to adopt, digital supervision practices. Caution is therefore warranted when generalizing these findings to other provincial contexts or different levels of education. Third, reliance on respondent self-reports renders the data susceptible to social desirability bias and common method variance, although the CMB test result (30.098%) remained within acceptable limits (Podsakoff et al., 2003). The incorporation of multiple data sources, such as direct observation or third-party assessments, in future studies would strengthen the external validity of the findings. Fourth, the research model examined only the direct SDC → DBSI relationship, without accounting for potential mediating or moderating variables, such as school digital infrastructure support, principal leadership, or supervisors' demographic characteristics (e.g., experience, age, and educational level). Future research is encouraged to explore the mediating role of teachers' digital competence and the moderating influence of regional policy contexts in strengthening or weakening the SDC–DBSI relationship, thereby developing a more comprehensive and practically applicable model to advance Indonesia's digital educational supervision system.

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