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Article

Increasing teacher professionalism through the implementation of digital academic supervision in Indonesian secondary school: Personal learning networks as mediator

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Abstract: This research investigates the impact of digital academic supervision (DAS) on teacher professionalism (TP), with a focus on the mediating role of personal learning networks (PLNs) and their implication for educational policy. Using Partial Least Squares Structural Equation Modeling (PLS-SEM), data were collected from 276 teachers in prestigious secondary schools in East Java, Indonesia. The study uses a regression model design to explore direct and mediated effects between DAS, PLNs, and TP. Findings demonstrate that DAS directly impacts both PLNs (0.638) and TP (0.550), while PLNs also directly influence TP (0.293). Mediated analysis indicates that DAS enhances TP through PLNs (0.187). These results underscore the importance of digital tools in academic supervision, fostering collaboration, and promoting teacher professional development. The empirical evidence supports the effectiveness of DAS in enhancing teacher professionalism, suggesting significant implications for educational policy and practice in Indonesia in terms of regulatory framework, such as data privacy and security, standardization, training programs, and certification and accreditation.

Keywords: digital academic supervision; personal learning networks; teacher professionalism; teacher competence; educational policy

1. Introduction

The widespread disruption in the industrial and business sectors has also unavoidably affected educational institutions. Consequently, there is a growing push for digital transformation in educational establishments, from elementary to secondary schools, to ensure their resilience amidst rapid changes. This pressure has intensified, especially with the global spread of the COVID-19 pandemic, prompting a broader recognition of the need for digitizing services. However, many institutions still face practical hurdles, precisely in Indonesia. A significant challenge lies in the support and development of teachers by their leaders, who hold the key to fostering digital literacy and accelerating service provision within school communities. Ultimately, the education system must equip students with the skills and competencies to navigate the evolving landscape, emphasizing critical thinking, problem-solving, collaboration, innovation, digital literacy, and adaptability (Elliott, 2017). In looking ahead to the future of education in 2030, the Former Organization

for Economic Co-operation and Development (OECD) emphasizes the importance of high-quality teachers in acquiring the necessary skills to tackle complex challenges and foster holistic personal development. They emphasize the importance of valuing equality, prosperity, sustainability, and well-being (OECD, 2019). A diverse set of skills and competencies is required to achieve this vision, enabling learners to act as "agents of change" who can positively impact their environment by developing empathy and anticipating the consequences of their actions.

As professional educators, teachers are a crucial determinant in achieving educational goals. This is because teachers directly interact with students to provide instruction, guidance, education, and experiences that contribute to producing the desired graduates (Mishan, 2014). furthermore, teachers are crucial elements contributing to the success of the learning process; it is imperative to uphold and constantly enhance teachers' performance. Achieving educational objectives becomes challenging when teachers' performance is lacking. This deficiency typically arises from a lack of teacher skills and professional improvement. It should be integrated with technology systematically and involve complex thinking, diverse information, collaboration, communication, and open planning among teachers and their colleagues (Liu et al., 2018; Lee and Ip, 2023). Click or tap here to enter text. Aligned with this, the digitization of the education sector is unstoppable, as it can support the continuity of valuable learning for students and teachers in dealing with medical emergencies caused by previous pandemic crises (Jain and Lamba, 2021). The efforts to combat the pandemic have opened up extensive opportunities for rapidly emerging digital technologies to play a significant role in the post-pandemic era (Azhari and Fajri, 2021; Mansyur, 2020; Yang et al., 2020).

Furthermore, it is essential to develop a governance model compatible with digital technology so that governance with digital guidance and leadership will become a standard component of the digital society (Peng, 2022). The supervision conducted by school principals on teachers significantly plays a crucial role in the enhancement of teachers' professional abilities and the improvement of teaching quality through practical learning. Furthermore, in the current context, digital academic supervision allows teachers to select meaningful programs while also allowing for flexible scheduling (Harris and Jones, 2017). Additional studies also demonstrate that digital academic supervision carried out by school principals and school supervisors has a substantial influence on enhancing teachers' professionalism (Huda and Muspawi, 2018; Lorensius et al., 2022; Nasution et al., 2022). Moreover, recent research also indicates a positive effect of the implementation of digital academic supervision by school principals in enhancing teachers' capacity (Fauzi et al., 2022; Mustabsyiroh et al., 2021; Rasdiana et al., 2024; Wiyono et al., 2021). These studies examine the relationship and direct influence of school principals' digital academic supervision on enhancing teachers' professionalism without considering other determinants that may affect its improvement.

Personal learning networks (PLNs), in several literature mentioned as professional learning networks for teachers, represent a promising approach as another determinant to achieve sustainable school improvement, particularly in enhancing teachers' professionalism (Krutka et al., 2016; Poortman et al., 2022).

These PLNs encompass every group engaged in collaborative learning with others outside their daily practice communities, aiming to improve student learning outcomes (Brown and Poortman, 2018). According to Stoll et al. (2006), PLNs are based on the same assumptions about how teachers learn and transform their teaching methods. Thus, PLNs represent one effort in teachers' professional development through interpersonal connections supported by resources to improve teachers' skills and knowledge. However, there are still weaknesses in the research efforts conducted. First, these studies only reviewed a set of procedures and implementation of virtual academic supervision by principals in a broad context (using ICT tools). They did not consider specific competency needs in teachers through quantitative analysis studies (such as digital literacy, teacher efficacy, and teachers' teaching practices in the use of ICT tools), which are crucial in improving the professionalism of teachers who are technologically literate in teaching activities. Second, these studies only describe the direct influence of digital academic supervision on teacher competency improvement. Thirdly, there is a research gap in the Indonesian school context, particularly in identifying how digital academic supervision affects the professionalism of tech-savvy teachers. Both Daly and Stoll (2018) and Johari et al. (2021) have analyzed the impact of digital academic supervision on improving teacher professionalism mediated by teachers' implementation of personal learning networks. Furthermore, improving teacher professionalism relies on critical thinking, collaboration between peers and stakeholders, open discussions, and easily accessible information in the workplace (Brown and Poortman, 2018).

Therefore, further examination of models for enhancing teachers' professionalism post-COVID-19 pandemic has become vital in the context of educational digitization in Indonesia. Implementing digital academic supervision by school principals has proven to be an essential factor that compels teachers to learn and enhance their capacity during the COVID-19 pandemic. Furthermore, PLNs have brought teachers together to address the challenges they face in their work, promoting their professional development as individuals and as a group. Consistent with research findings in Malaysia by Johari et al. (2021), teachers with networking, teamwork, technological facilities, and principal support are likelier to engage in innovative teaching behavior and professional development. The findings suggest that teachers often use humor in their networking, which can foster teaching innovation. Finally, this study we conduct will focus on analyzing and exploring the role of digital academic supervision by school principals in enhancing teacher professionalism mediated by personal learning networks and their implication precisely for educational policy. Therefore, it would be incredibly beneficial for teachers to learn highly effective procedures for their professional development through pedagogical innovation in the classroom, facilitated by the PLNs they build to enhance their educational efforts.

2. Literature review and hypotheses development

2.1. Preliminary studies towards conceptual framework

Improving teachers' professionalism is essential to improving teaching and

instruction in the digital age. Teachers must keep up with technological advancements across various areas of professional development. Supervision should guide effective professional growth through interactive, collaborative, technology-based models tailored to individual needs and interests, utilizing appropriate resources and execution methods (Darling-Hammond and Wei, 2009). Time constraints often limit teachers' ability to initiate meaningful professional development beyond tasks set by administrators in the school schedule. Consequently, administrators frequently determine the agenda for teacher professional growth, scheduling it at specific times like semester breaks (Wei et al., 2010). Teachers and supervisors may not always agree on the most crucial professional development topics, with teachers sometimes viewing it solely as a means to meet certification renewal requirements. Based on the previously mentioned studies, the following conceptual framework can be proposed to illustrate the relationship between variables in this study.

Digital academic supervision allows teachers to choose meaningful programs while offering flexibility in scheduling. Research on the impact of online professional development on teaching is still limited. This conceptual framework is consistent with Elliot's (2017) theory of effective professional development and aims to enhance teaching by integrating technology to improve student learning outcomes. **Figure 1** illustrates the revised future development of teacher professionalism as a continuation of results and ongoing efforts.

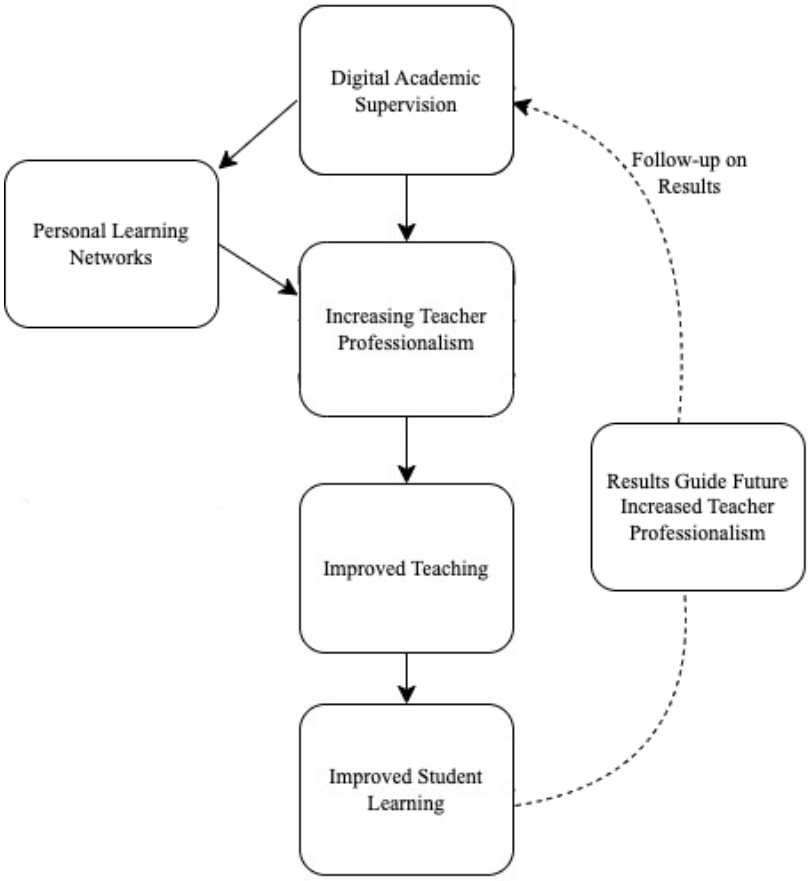

Figure 1. Visualization of conceptual framework based on preliminary studies.

2.2. Interconnections between DAS, TP, and PLNs

The role of personal learning networks (PLNs) is examined within the framework of secondary education in Indonesia. Further investigation is necessary to delve into how PLNs facilitate digital academic supervision and its impact on enhancing teacher professionalism. The various stages of digital academic supervision and engagement in PLNs each play a role in fostering improvements in teacher professionalism (Campbell et al., 2016; OECD, 2020). Initially, the pre-observation assessment stage involves collaborative activities centered around shared values and vision, emphasizing joint responsibility for enhancing student learning outcomes. This phase contributes significantly to the ethical and psychological development of teachers, encompassing aspects such as rights and responsibilities, spiritual values, self-assessment, and the integration of humor and learning (Ismail, 2018; Rusmaniar et al., 2023).

Secondly, during the observation assessment stage, supervisors focus on recognizing learning characteristics and facilitating teachers' use of digital media and tools (Guntoro, 2016; Saihu, 2020; Xie, 2017). This phase is pivotal for nurturing professional skills and advancing a teacher's career trajectory, encompassing areas such as curriculum and pedagogical knowledge, digital literacy, and fostering peer relationships (Haleem et al., 2022; Nisa, 2023; Xie et al., 2017).

Thirdly, in the solution provision stage, collaboration is prioritized among principals, teachers, and external colleagues (such as those from other schools, researchers, and policymakers) (Aloisi and Scana, 2016; Elkordy and Zumpano, 2018; Menard and Olivier, 2014; Winnips et al., 2019). This collaboration is instrumental in addressing all facets of enhancing teacher professionalism, including professional skills, ethical conduct, and career development. Finally, the reflection and follow-up stage encourage teachers to refine their skills and foster collaboration by engaging in PLNs activities focused on collaboration and instructional feedback. These PLNs activities are designed to facilitate an active and continuous learning process for educators through discussions and reflective discourse (Amaya et al., 2018).

2.3. Teacher professionalism (TP)

Enhancing teacher professionalism is essential for sustainable development. Within a coaching relationship, individuals reflect on their strengths, challenges, and experiences to gain insights and experiment with new ideas and behaviors (Patti et al., 2015). The successful Adoption of the coaching model requires adequate time to find skilled coaches, offer support in various areas, and provide training to coaches before they engage with teachers (Lloyd and Mod, 2012). Improving teacher professionalism is closely linked to efforts to enhance knowledge for future work and is integrated with other activities to modify work behavior (A Noe, 2013; Hariandja, 2007; Musriadi, 2016).

The characteristics of teacher professionalism can influence students' intellectual and personal development (Anwar, 2018). Several studies have indicated the professional characteristics of teachers in enhancing student abilities (Adak et al., 2018; Cubero, 2022; İlğan et al., 2022). According to Anwar (2018), indicators of

teacher professionalism include: 1) possessing relevant professional knowledge encompassing advanced theoretical and methodological knowledge; 2) understanding the curriculum and pedagogical content in the field; 3) awareness of their rights and responsibilities as teachers and individuals; 4) consideration of spirituality and universal values; 5) incorporating humor; 6) evaluating their performance; and 7) fostering positive and warm relationships with their students.

Leithwood (2007) proposes three dimensions of teacher development that can be influenced by digital principles: psychological development, professional skill development, and career cycle development. Leithwood (2007) explicitly highlights that teachers' professional skill development will impact students, schools, and improvements related to systems or policies at all levels. Teacher professional enhancement is divided into three parts (Glatthorn, 1995; Rahayu et al., 2019): 1) intensive development, which is a form of development carried out by leaders or superiors towards teachers intensively based on their needs. This model is usually conducted systematically, from planning and implementation to evaluation and feedback meetings or reflections; 2) cooperative development, a form of teacher development carried out systematically through collaboration with peers in a team. The goal is to enhance teachers' professional abilities through peer input, advice, guidance, or assistance; and 3) self-directed development, a form of development carried out through self-directed means. This form provides broad autonomy to teachers, enabling them to plan activities, implement and analyze them, and provide feedback for self-development.

2.4. Digital academic supervision (DAS)

Digital academic supervision is multifaceted and includes a) being web-based, b) focusing on the professional growth of teachers, and c) having specific objectives tailored to individual needs (Hahs-Vaughn et al., 2017). As per Hernández-Gantes (2010), digital academic supervision refers to professional coaching for teachers delivered via the Internet in both formal and informal classroom settings, with a personalized structure. This approach may incorporate visual videos, interactive elements, readings, assessments, discussions, and other learning resources. Digital academic supervision can provide broader content and enhance accessibility, particularly for schools in rural areas and specific program content (Rasdiana et al., 2024). Furthermore, digital academic supervision provides a way to address some challenges by offering greater flexibility regarding when and where teachers can engage and increasing content accessibility to more schools. These challenges often stem from schools lacking adequate time and resources to provide coaching, as it is mainly conducted after school hours and during school breaks, both of which are also needed for planning and addressing issues during the academic year (Wei et al., 2010; Yoon, 2022). The digital academic supervision model goes beyond training sessions, workshops, meetings, and seminars. It is seen as a continuous, career-spanning process contextualized and guided by standards rooted in teacher duties, centered on student learning, and customized to meet teachers' needs (Jimoyiannis et al., 2011).

Various expert researchers have modified the primary conceptual dimensions of

digital academic supervision for teacher professional development. Initially, a comprehensive model has been successful in practice, being both integrated and inclusive, resembling a comprehensive approach. Secondly, concerning PLNs, this model goes beyond formal education to embrace non-formal learning, addressing lifelong needs, being reactive rather than deliberative, and fostering collaboration over individual efforts (Williams, 2003; Williams et al., 2007). Thirdly, the merging of advantages of e-learning, which relies on asynchronous interaction, offers two alternatives not feasible in traditional face-to-face settings (Dettori et al., 2006). This includes essential functions like calling and chatting and interface interactions such as website navigation, sending, and receiving messages (Arbaugh, 2004). Fourthly, regarding equal opportunities, Keown (2009) suggests that digital academic supervision is a promising way to provide professional development for teachers on a broad scale. Fifthly, concerning social efforts, digital academic supervision adopts social learning theory, which views cognition as situational, social, and distributed (Putnam and Borko, 2000). Lastly, acting as a catalyst for change, engagement in digital academic supervision processes allows individuals to expand their scope of action, leading to new learning trajectories and career paths (Allan and Lewis, 2006).

Based on insights from previous research models, the adapted stages of digital academic supervision, as also advocated by Mustabsyiroh et al. (2021), entail several vital steps. Initially, in the pre-observation phase, supervisors and teachers engage in interviews using digital platforms such as Google Meet, Zoom Meeting, or WhatsApp Call/Video. During this phase, educators can transmit necessary documents like modules and syllabi to supervisors via platforms like Google Docs, WhatsApp Doc, or Email. Subsequently, supervisors may prompt educators to complete supervision instruments through platforms like Google Forms. Moving to the implementation stage, supervision activities occur through various digital platforms, aligning with those utilized in the educators' teaching processes. Teachers then forward video conference links to supervisors for observation. Following the supervision session, supervisors analyze observation outcomes, facilitating post-lesson discussions with educators. Finally, in the result dissemination phase, supervisors share observation findings with educators through email, WhatsApp, and others. These stages collectively facilitate a structured and efficient approach to digital academic supervision, enhancing professional development opportunities for educators.

2.5. Personal learning networks (PLNs)

PLN, or personal learning networks, are learning networks that may comprise teachers, school leaders, collaborators with researchers, or policymakers who come together alongside others beyond their daily professional activities to engage in collaborative learning to enhance teaching and student learning outcomes. The concepts for both personal learning networks (PLNs) and professional learning communities (PLCs) are similar; the main idea of PLCs consistently revolves around enhancing student learning outcomes by elevating the quality of teaching provided by teachers (Clark et al., 2023). PLNs may also concentrate on issues related to well-being or equity or critically examine curriculum objectives (Brown, 2020; Datnow

and Park, 2018). Furthermore, Farooq et al. (2007) suggest three design strategies for sustaining PLNs: 1) investing in cohesive social connections, 2) providing diverse online platforms for community involvement, and 3) strengthening the organic leadership role emerging from within the community.

Daly and Stoll (2018) emphasize the need for a more precise definition of PLNs to make them practical tools for improving teacher and student learning outcomes. Stoll et al. (2006) propose five essential characteristics or elements of PLNs: (1) shared values and vision; (2) collective responsibility; (3) reflective professional inquiry; (4) collaboration; and (5) the advancement of learning for individuals and groups. Lomos et al. (2011) discuss the critical dimensions of the concept, which include: (1) reflective dialogue; (2) opening up practices or providing feedback on instruction; (3) collaborative endeavors; (4) a shared sense of purpose; and (5) a collective focus on student learning.

Finally, drawing upon the statements from the literature review, we propose and formulate hypotheses in this study, as depicted in **Figure 2**.

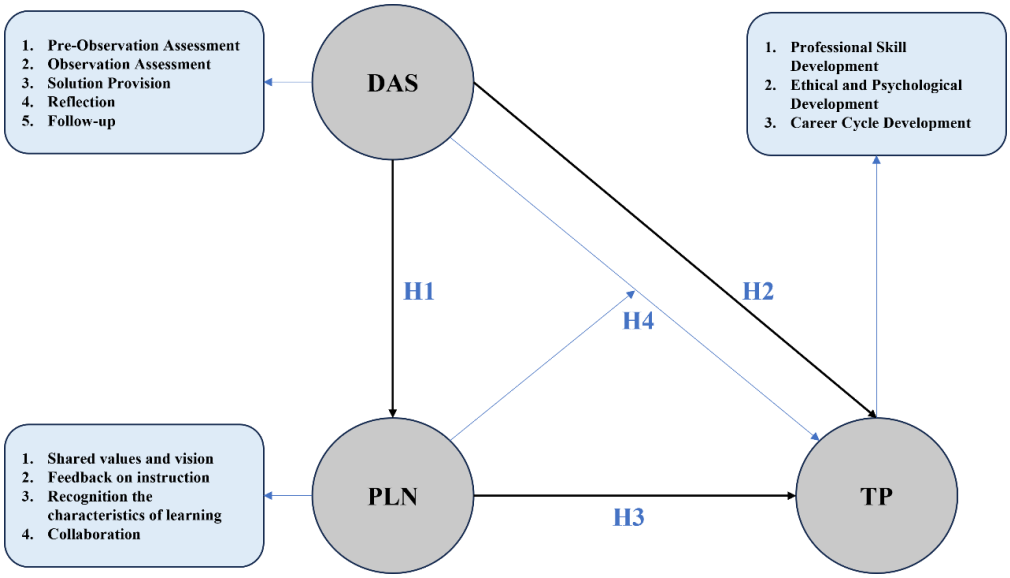

Figure 2. Visualization of hypotheses development.

Figure 2 presents the hypothesis path, which serves as a broader explanation of the relationships between variables depicted in the diagram. This visual representation offers a detailed insight into the interconnectedness and potential causal effects among the factors under consideration.

H1: The influence of DAS on PLN.

H2: The influence of DAS on TP.

H3: The influence of PLN on TP.

H4: The influence of DAS on TP mediated by PLN.

3. Materials and methods

This section contains several explanations regarding the methodology guidance we used in conducting this research, including guidance on research design, participant and procedure, instrument, and analysis.

3.1. Research and study design

This study was designed using a quantitative methodology, employing structural equation modeling with partial least squares (PLS-SEM) following the approach outlined by Hair et al. (2021a). Surveys in the form of questionnaires were used to assess the alignment between theoretical and empirical models, following Creswell's (2014) guidance. Data acquisition was conducted from 31 July 2023, to 22 September 2023. The study aimed to explore how structural variables tied to digital academic supervision (DAS) influence personal learning networks (PLN) and teachers' professionalism (TP).

3.2. Participant and procedure

This study focuses on high school teachers from prestigious schools in East Java, with a sample size of 276 teachers determined using quota sampling. The sample proportions are based on the percentage of supervised teachers in each school, ensuring representation across the population of 950 teachers (Futri et al., 2022). Therefore, we determined sample proportions by considering the percentage of supervised teachers in each school relative to the total population. These proportions are then multiplied by the target sample size. The sample size is determined using statistical equations and Krejcie and Morgan's (1970) table, ensuring methodological rigor and accuracy in sample selection. **Table 1** represents the population and sample in our study.

Table 1. Population and sample distribution.

Province demographic region (East Java)	Total teachers (population)	Proportion	Total samples (proportion × 276)	Rounded
Northern (2 schools)	160	0.16	46.13	47
	172	0.18	49.68	50
Central (1 school)	143	0.15	41.4	42
West (2 schools)	134	0.14	38.64	39
	219	0.23	63.48	64
South (1 school)	122	0.12	33.12	34
Total	950			276

Table 1 serves as a guide for obtaining a proportional sample from each school, ensuring that respondents are obtained as needed and that the subsequent analysis accurately reflects the entire study population.

3.3. Instrument

In this sub-section, we present indicators of latent variables (DAS, PLNs, and TP) used as a measurement to gather data from our research respondents (see Appendix).

3.3.1. Teacher professionalism (TP)

This concept is related to structured efforts to enhance educational organizations' capabilities and productivity through the development and empowerment of teachers. This is achieved through actions focusing on (1) ethical

and psychological development, (2) professional skill enhancement, and (3) career cycle development (Glatthorn, 1995; Leithwood, 2007; Rahayu et al., 2019). Before distributing the instrument questionnaire to actual samples, we developed a validity and reliability assessment conducted in another school with the same characteristics as our research population using a Likert scale of 5 (strongly agree) to 1 (strongly disagree). The convergent validity analysis resulted in a range of 0.752 to 0.928. Meanwhile, Cronbach's alpha result was 0.934 in excellent category. Nine items were selected and used in the questionnaire.

3.3.2. Digital academic supervision (DAS)

DAS pertains to the role of principals as supervisors in providing support and services to foster and improve teachers' competencies in enhancing the quality of teaching, learning, and curriculum development, all facilitated digitally. This process entails several stages: (1) pre-observation assessment, (2) observation, (3) providing solutions, (4) reflection, and (5) follow-up (Jimoyiannis et al., 2011; Mustabsyiroh et al., 2021). The convergent validity analysis of the pilot study resulted in a range of 0.756 to 0.909. Meanwhile, the Cronbach's alpha result was 0.928 in an excellent category. Seven items were used in the questionnaire.

3.3.3. Personal learning networks (PLNs)

PLNs refer to the relational system among teachers or colleagues as resources supporting the enhancement of teachers' competencies and knowledge to improve student learning outcomes ultimately. This is guided by four main criteria: (1) shared values and vision, (2) feedback on instruction, (3) recognition of learning characteristics, and (4) collaboration (Daly and Stoll, 2018; Poortman et al., 2022). The convergent validity analysis resulted in a range of 0.753 to 0.818. Meanwhile, Cronbach's alpha result was 0.856, categorized as good. Five items were selected in the questionnaire.

3.4. Analysis guidance

Before hypothesis testing, the research data analysis via the SmartPLS4 application encompasses various stages, such as reflective, formative, and structural model analyses. These steps incorporate analytical calculations, namely the PLS algorithm and bootstrapping (Hair et al., 2021; Sarstedt et al., 2021). During the reflective analysis phase, we will commence with analyses that include indicator reliability, internal consistency reliability, convergent validity, and discriminant validity (Sarstedt et al., 2021). First, in assessing indicator reliability, we typically regard outer loading values of 0.7 or higher as demonstrating satisfactory reliability (Sarstedt et al., 2021). Nonetheless, values exceeding 0.5 remain acceptable, particularly within social science research (Collier, 2020). Second, Cronbach's alpha and Composite reliability assess the internal consistency of latent variables. The acceptable range for exploratory research is 0.60–0.70 and 0.70–0.90 for advanced stages. Composite reliability should exceed 0.70 (Hair et al., 2021; Sarstedt et al., 2021). Third, the prevalent metric for convergent validity is the average variance extracted (AVE). It is recommended that the AVE value exceeds 0.5 to indicate satisfactory levels of convergent validity (Sarstedt et al., 2021). Fourth, in assessing discriminant validity, we utilize two measurement approaches: the Fornell-Larcker

criterion and the Heterotrait-Monotrait Ratio (HTMT). Furthermore, a favorable HTMT value fit is ≤0.90 (Hair et al., 2021).

Furthermore, in the formative analysis within Partial Least Squares Structural Equation Modeling (PLS-SEM), we use two key steps: Collinearity assessment and Significance and Relevance assessment. Firstly, in assessing collinearity in PLS-SEM, the variance inflation factor (VIF) is a measure used to determine the extent to which the variance of estimated regression coefficients increases if predictors are correlated, emphasizing that the threshold value for VIF should ideally be less than 5 or 10 (Sarstedt et al., 2021). Secondly, the significance and relevance of variables are assessed using the outer weight (*P* value) at a 5% significance level, which ideally should be less than 0.5. Additionally, the *t*-statistic, commonly used for two-tailed tests, has a critical value of 1.96 at a 5% they are significance level (Sarstedt et al., 2021). Finally, structural model assessment consists of the Goodness of fit assessment and path coefficient (Hair et al., 2023; Sarstedt et al., 2021). Specifically, model fit can be assessed through various criteria in SmartPLS4. A good fit is typically indicated when the Standardized Root Mean Residual and Non-Fit Index values meet certain thresholds: SRMR ≤ 0.10. d_ULS ≥ 0.05, d_G ≥ 0.05, chi-square ≤ 3.00 (or preferably small), and NFI ≥ 0.80 (Edeh et al., 2023). Additionally, the path coefficient is commonly utilized to measure the strength and direction of the relationship between two latent variables or between a latent variable and its indicators (Sarstedt et al., 2021).

4. Results

This section explains our research findings, including the respondent profile, descriptive statistics, and analysis results using PLS-SEM from reflective assessment to structural assessment for hypotheses.

4.1. Respondent demographic distribution

In this sub-section, we will present several aspects of respondent profiles based on gender, age, level of education, professional certifications, and length of work experience.

Table 2. Demographic profile of participants (*n* = 276).

Aspects	Frequency	Percentage
Gender		
Male	124	44.92%
Female	152	55.08%
Age (years)		
20–25	75	27.17%
26–34	124	44.93%
35–54	77	27.9%
More than 55 years	-	-
Education level		
Bachelor	135	48.91%
Master	30	10.86%

Table 2 reveals that the study's respondents are predominantly female, comprising 55.08% of the total sample based on gender distribution. The most prevalent age group falls within the 26–34 range, representing 44.93% of respondents, indicating a substantial presence of junior and senior educators. Regarding educational attainment, a significant portion of respondents hold bachelor's degrees, totaling 135 individuals or 48.91%. Furthermore, 88 respondents, equivalent to 31.90%, possess professional certifications. Finally, most teachers have over five years of work experience, accounting for 81.16% of the total sample.

4.2. Descriptive statistics

Table 3, presented below, showcases descriptive statistics for each survey item, encompassing key metrics such as means, standard deviations, skewness, kurtosis, and critical ratio. These measures are essential indicators for evaluating the data's normality, providing valuable insights into the variables' distributional characteristics.

Table 3. Variables descriptive statistics.

Observed variables	*N*	Min	Max	Mean	Std. deviation	Skew	Kurtosis
DAS1	276	1.000	5.000	4.167	0.848	−1.259	2.119
DAS2	276	1.000	5.000	4.225	0.864	−1.468	2.729
DAS3	276	1.000	5.000	4.163	0.751	−0.949	1.768
DAS4	276	1.000	5.000	4.138	0.853	−1.501	3.325
DAS5	276	1.000	5.000	4.047	0.881	−1.465	3.058
DAS6	276	1.000	5.000	4.402	0.713	−1.369	3.085
DAS7	276	1.000	5.000	4.362	0.701	−1.465	4.062
PLN1	276	1.000	5.000	4.203	0.906	−1.558	2.854
PLN2	276	1.000	5.000	4.217	0.899	−1.587	3.159
PLN3	276	1.000	5.000	3.833	1.123	−1.178	0.840
PLN4	276	1.000	5.000	4.036	0.912	−1.080	1.235
PLN5	276	1.000	5.000	3.935	0.980	−1.194	1.387
TP1	276	1.000	5.000	4.312	0.778	−1.488	3.583
TP2	276	1.000	5.000	4.388	0.751	−1.498	3.478
TP3	276	1.000	5.000	4.337	0.706	−1.331	3.450
TP4	276	1.000	5.000	4.388	0.731	−1.591	4.282
TP5	276	1.000	5.000	4.391	0.784	−1.675	3.998
TP6	276	1.000	5.000	4.264	0.789	−1.398	3.192
TP7	276	1.000	5.000	4.330	0.801	−1.688	4.235
TP8	276	1.000	5.000	4.449	0.682	−1.402	3.465
TP9	276	1.000	5.000	4.435	0.675	−1.430	3.918

As Collier (2020) outlined, the assessment of data normality adheres to specific criteria. Verify that the Skewness value equals or is less than 1, ensure that the r (coefficient of reliability) is less than 8, and confirm that the kurtosis falls within the range of −10 to 10. **Table 3** provides evidence suggesting that the data for each

observed variable conforms to a normal distribution, thereby meeting the established criteria for normality assessment.

4.3. Reflective assessment

The reflective assessment we will present in this section encompasses convergent validity, internal consistent reliability, and discriminant validity, depicted in **Tables 4** and **5**.

Table 4. Convergent validity & internal consistency.

Item	Item code	Cronbach's alpha	rho_A	Loading	CR	AVE
Digital academic supervision (DAS)	DAS1	0.888	0.893	0.779	0.913	0.600
	DAS2			0.831		
	DAS3			0.728		
	DAS4			0.842		
	DAS5			0.816		
	DAS6			0.710		
	DAS7			0.702		
Personal Learning network (PLN)	PLN1	0.865	0.873	0.830	0.902	0.649
	PLN2			0.857		
	PLN3			0.761		
	PLN4			0.756		
	PLN5			0.818		
Teacher professionalism (TP)	TP1	0.923	0.927	0.755	0.936	0.620
	TP2			0.811		
	TP3			0.794		
	TP4			0.816		
	TP5			0.734		
	TP6			0.767		
	TP7			0.782		
	TP8			0.798		
	TP9			0.827		

Note: $N = 276$; AVE = Average variance extracted; CR = Construct reliability; DAS = Digital academic supervision; PLN = Personal learning network; TP = Teacher professionalism.

Table 4 confirms that the outer loading thresholds in our research have been met satisfactorily. This assertion is supported by the observation that the items comprising each latent variable—DAS, PLN, and TP—exhibit values exceeding 0.7, indicating robust relationships with their respective constructs. Additionally, the average variance extracted (AVE) values surpass the threshold of 0.5, underscoring the adequacy of convergent validity. Moreover, Cronbach's alpha and composite reliability (CR) consistently demonstrate values greater than 0.7, affirming the reliability and internal consistency of the measurement model. Subsequently. discriminant validity is assessed further in **Table 5**.

Table 5 shows correlation values below 0.90 between latent variables. indicating their uniqueness. This allows for further analysis (Hair et al., 2021).

Table 5. Discriminant validity: Heterotrait-Monotrait Ratio (HTMT).

	DAS	PLN	TP
DAS			
PLN	0.716		
TP	0.602	0.571	

4.4. Formative assessment

In this section, we provide an assessment of the variance inflation factor (VIF) Assessment for the uniqueness of variable latent assessment, as depicted in **Table 6**. Subsequently, we obtained the significance assessment through bootstrapping, presented in **Table 7**.

Table 6. Variance inflation factor (VIF) assessment.

Items (sub indicators)	VIF
DAS1	2.023
DAS2	2.644
DAS3	1.866
DAS4	3.453
DAS5	3.570
DAS6	1.964
DAS7	1.887
PLN1	2.417
PLN2	2.571
PLN3	1.876
PLN4	1.810
PLN5	1.986
TP1	2.052
TP2	2.881
TP3	2.391
TP4	2.773
TP5	2.604
TP6	2.527
TP7	3.246
TP8	3.159
TP9	2.906

VIF (variance inflation factor) gauges the extent to which the variance of estimated regression coefficients escalates when predictors are correlated. The recommended threshold for VIF is typically below 5 or 10. **Table 7** indicates that all indicator items surpass this threshold. as each value falls below 5.

Table 7 reveals that all path analyses hypothesized in our study lead to rejecting the null hypothesis (H0). This indicates that all proposed hypotheses are acceptable, supported by p-values < 0.05 and t-statistics > 1.96. Consequently, it can be inferred that DAS significantly influences PLN and TP. Furthermore, the impact of PLN on

TP is also significant. Ultimately. the proposed mediation hypothesis, suggesting that DAS affects TP through the mediation of PLN, holds significance.

Table 7. Significance assessment.

Path	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	*T* statistics (|O/STDEV|)	*P*-values	Confidence interval		Decision
						5%	95%	
DAS → PLN	0.638	0.638	0.055	11.647	0.000	0.524	0.735	Accepted
DAS → TP	0.550	0.551	0.083	6.636	0.000	0.380	0.695	Accepted
PLN → TP	0.293	0.300	0.074	3.962	0.000	0.128	0.417	Accepted
DAS → PLN→ TP	0.187	0.191	0.047	3.949	0.000	0.089	0.278	Accepted

Note: $p \leq 0.05$ (two-tailed test); DAS = Digital academic supervision; PLN = Personal learning network; TP = Teacher professionalism.

4.5. Structural assessment

The assessment we present in this structural analysis consists of model fit results using SmartPLS4 software. depicted in **Figure 3** and **Table 8**. Furthermore. we analyzed the total effect of latent variables and hypotheses in **Table 9**.

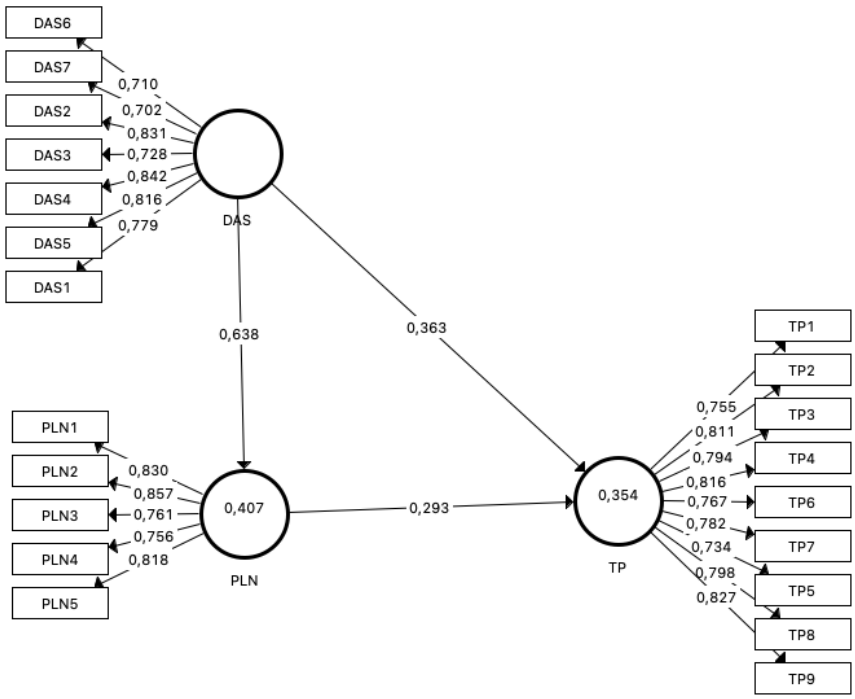

Figure 3. Measurement model.

Table 8. The Goodness of fit statistics model SmartPLS4.

	Saturated model	Estimated model	Conclusion
SRMR	0.079	<0.08	Good fit
d_ULS	1.429	>0.05	Good fit
d_G	0.697	>0.06	Good fit
Chi-square	1017.413	<3.00	Fit enough
NFI	0.754	>0.80	Fit enough

Table 8 demonstrates that the model's findings (saturated model) meet the reference standard (estimated model), suggesting that the model in this study is congruent with the available data in the field. As a result, further bootstrapping analysis can be conducted to explore the relationships between variables. Based on this result. we finally assess the coefficient effect of latent variables based on our proposed hypotheses.

Table 9. Summary of hypotheses testing total effects.

Hypotheses	Path	Direct effect	Indirect effect
H1	DAS → PLN	0.638	
H2	DAS → TP	0.550	
H3	PLN → TP	0.293	
H4	DAS → PLN → TP		0.187

Table 9 shows that, the impact of DAS on PLN is 0.638 and that DAS on TP is 0.550. Furthermore, the cumulative effect contributed by PLN to TP is 0.293. The total impact contributed by DAS to TP, when mediated by PLN, amounts to 0.187. Based on these collective effect findings, it is evident that the introduction of PLN as a mediator of DAS substantially enhances TP by 18.7%. This underscores the significance of PLN's role, with implications to be further elucidated in the subsequent discussion section.

5. Discussion

The main objective of this research is to examine the effect of digital academic supervision on improving teacher professionalism. Additionally, this research investigates the influence of personal learning network mediation on digital academic supervision in secondary schools.

5.1. The influence of DAS to TP (H1)

Specifically, the initial findings of this research study indicate that the implementation of digital academic supervision influences teachers' professionalism. The application of digital academic supervision theory is a novel approach, and this study adds to the evidence supporting the claim that digital academic supervision is influential. It reveals that digital academic supervision can optimize teacher practice communities like PLNs, as PLNs facilitate the exchange of information, acquisition, and development of various types of knowledge essential for effective teaching in schools. These outcomes corroborate existing theories, such as those proposed by Aldawood et al. (2019), Dalawi et al. (2013) and Jaenudin (2017) highlighting the significant influence of digital academic supervision on improving teacher professionalism. Through dedicated efforts in both the development and empirical examination of digital academic supervision, studies conducted by Guntoro (2016), Saihu (2020) and Xie (2017) underscore the pivotal role of digital academic supervision in elevating teacher professionalism within educational settings. Notably, Xie (2017) reveals that a year-long professional development initiative aimed at aiding teachers in assessing and selecting digital learning materials could

serve as a viable framework for enhancing teachers' proficiency in integrating educational technology—particularly beneficial for less-experienced educators. Moreover, qualitative analyses provide valuable insights for designing successful future professional development programs.

This research offers empirical evidence to expand digital academic supervision's influence on teacher professionalism's advancement, particularly within the Indonesian context. The initial observations regarding digital academic supervision arose globally as a response to the pandemic, which compelled individuals to remain indoors while pursuing personal development to adapt to evolving circumstances (Samiya et al., 2022). In Indonesia, the efficacy of digital academic supervision has been underscored, with evidence indicating that its implementation enhances teacher performance and the competencies of supervisors (Amiruddin, 2019; Kasmawati, 2020; Khilmiyah et al., 2021; Purpuniyanti and Dwikurnaningsih, 2021; Wiyono et al., 2022). Applying digital academic supervision to elevate teacher professionalism in prominent secondary schools (SMA/MA) in East Java has fostered constructive and efficient practices. This has empowered supervisors to support teaching and learning through technology, resulting in heightened pedagogical competencies among teachers, optimal student achievement, and the establishment of effective schools that garner community trust. These adaptable concepts, in alignment with the shifting zeitgeist, can be tailored as educators gain experience or confront challenging scenarios. The interplay between teachers' knowledge, teaching and learning frameworks, and the practical landscape of education is pivotal for comprehending the trajectory of professional teacher development.

5.2. The influence of DAS to PLN (H2)

The second hypothesis indicates that digital academic supervision (DAS) influences the teacher's learning network (PLN). In the dynamic realm of modern education, using digital tools has become indispensable in enriching academic supervision procedures. This, in turn, strengthens PLNs and facilitates collaborative advancement. Firstly, before the observation phase begins, digital platforms like WhatsApp serve as effective channels for communication between supervisors and teachers. Supervisors can utilize WhatsApp groups to share resources, set expectations, and clarify objectives for upcoming observations. By fostering open communication and providing relevant materials beforehand, supervisors can ensure that teachers are well-prepared and aligned with the goals of the observation process. Secondly, during the observation phase, platforms such as Zoom and Google Meet offer the flexibility to conduct virtual classroom visits. Supervisors can observe teaching practices in real-time through live streaming or recorded sessions or review recordings at their convenience. These digital platforms overcome logistical constraints and allow for greater accessibility and inclusivity, enabling supervisors to provide timely feedback regardless of geographical distances. Thirdly, following the observation, digital platforms are pivotal in facilitating constructive feedback and solution provision. Supervisors can use messaging apps like WhatsApp to share personalized feedback, commend exemplary practices, and suggest areas for

improvement. Additionally, Zoom and Google Meet offer one-on-one coaching sessions, where supervisors can delve deeper into specific instructional strategies and provide targeted support tailored to individual teacher needs. Furthermore, reflection is a critical component of the professional learning process, and digital platforms offer convenient avenues for teachers to engage in self-reflection and peer collaboration. WhatsApp groups can serve as virtual communities where teachers share reflections, pose questions, and exchange insights gained from the observation experience. Through asynchronous discussions and reflective prompts, teachers can deepen their understanding of pedagogical practices and refine their teaching approaches collaboratively. Finally, digital platforms enable seamless follow-up and ongoing support beyond the observation phase. Supervisors can schedule follow-up Zoom or Google Meet meetings to revisit goals, monitor progress, and provide additional resources or training opportunities. Moreover, WhatsApp groups serve as dynamic forums for continued dialogue, where teachers can seek guidance, celebrate successes, and collectively problem-solve challenges encountered in their practice.

The above explanations indicate that by leveraging digital tools throughout the academic supervision process, supervisors can enhance teacher PLNs' ability to share a common vision, provide constructive feedback on instruction, recognize diverse learning characteristics, and foster collaboration. Through effective communication, personalized support, and reflective dialogue, digital-based supervision empowers teachers to continuously grow, adapt, and excel in their professional practice. There is also a positive and strong relationship between teachers' participation in PLNs activities, especially collaborative-PLN activities, with teachers' professional development and coaching (Campbell et al., 2016; OECD, 2020). In that study, engagement in PLCs was measured using group-based PLNs activities, such as teachers' level of participation in team teaching, conducting collaborative action research, and visiting other schools to observe better professional practices and adapt to their school context. Aligned with a study by Ismail (2018) emphasizing the importance of academic supervision in the digital age, necessitating educators to continually upgrade their professional learning and teaching approaches to foster high-order thinking, constructivist learning, cooperative strategies, recognition of multiple intelligences, and the integration of technology for students' independent access to information and digital ethics practice. Additionally, Rusmaniar et al. (2023) discovered that digital-based academic supervision activities prioritize a thorough evaluation of the quality of teacher assignment implementation over mere administrative completeness. The utilization of digital tools in providing individualized technical academic supervision yields a positive impact on the instructional process by the teacher and the learning quality of the students. Consequently, Academic supervision, bolstered by the support of the principals, plays a pivotal role in enhancing teachers' preparedness and proficiency in effectively utilizing information and communication technology (ICT). Through collaborative efforts and guidance provided during supervision sessions, educators are equipped with the necessary skills and knowledge to optimally leverage ICT tools and resources, thereby fostering a conducive learning environment that aligns with the demands of the modern educational landscape (Istiningsih et al., 2020).

5.3. The influence of PLN to TP (H3)

The research findings further corroborated the acceptance of H3 as outlined in our study objectives. This indicates that teachers' learning networks (PLNs) embody shared values and visions, offer constructive feedback on instructional processes, demonstrate a comprehensive understanding of the learning process, and actively engage in collaborative efforts with various stakeholders, both within and beyond the school environment, contributes to the enhancement of their professionalism, encompassing the development of their professional skills, ethical and psychological growth, and progression through their career cycle. The indicators of personal learning networks (PLNs) have a significant impact on various facets of teacher professionalism. Firstly, shared values and visions within a teacher's PLN foster a sense of cohesion and alignment with broader educational goals, enhancing their professional identity and commitment to their profession. Secondly, PLNs that provide constructive feedback on instructional processes enable teachers to reflect on their teaching practices, identify areas for improvement, and refine their pedagogical approaches. This reflective practice is fundamental to professional growth and development. Thirdly, a comprehensive understanding of the learning process within PLNs equips teachers with the knowledge and strategies needed to facilitate student learning and academic achievement effectively. This contributes to their competence as educators and enhances their professional standing. Finally, active collaboration within PLNs, both within and beyond the school environment, promotes networking opportunities, knowledge sharing, and the exchange of best practices. This collaborative engagement enriches teachers' instructional strategies and nurtures a supportive professional community, fostering their professional well-being and career advancement.

This finding is consistent with the study by Katz and Earl (2010) that networked learning communities can facilitate profound learning, promote paradigm shifts in thinking and methodology, and enhance student achievement through collaborative systems within the network and the participating schools. Similarly, Krutka et al. (2016) found that professional learning networks can facilitate teachers' professional and their personal growth through active engagement, exploration, experimentation, reflection, and knowledge exchange. Finally, various studies suggest that PLN technology is crucial to enhancing service learning by boosting participation, engagement, and collaboration, all the while improving project coordination and integration (Aloisi and Scana, 2016; Elkordy and Zumpano, 2018; Menard and Olivier, 2014; Winnips et al., 2019). Therefore, the study also shows how recognizing the importance of innovation in teaching and learning affects how teachers connect with others professionally. Teachers show this by actively learning new teaching methods, valuing teamwork with colleagues, and working together to understand teaching materials better. This supports what Sargent (2015) emphasized: even if teachers are unsure about educational changes, new teaching ideas spread well when teachers share and learn from each other within school groups and broader networks. Recent mixed-method research indicates a significant correlation between innovative teaching practices and using PLNs (Clark et al., 2023). Participants emphasize the role of relationships in cultivating an innovation culture

through sharing their insights. They also value innovative pedagogical approaches, which positively impact attitudes towards PLNs. Enhancing mechanisms for evaluating successful innovations is vital for improving student learning outcomes in an evolving learning environment (Barshay, 2018).

5.4. The influence of DAS to TP mediated by PLNs (H3)

Finally, the research findings reveal a significant correlation between digital academic supervision and the mediating role of personal learning networks, which positively influences the enhancement of teacher professionalism (H4). This finding is consistent with previous studies that have identified the significant influence of personal learning network mediation on principal supervision and the improvement of teacher professionalism (Hargreaves and Fullan, 2012; Hinojo-Lucena et al., 2019; Johari et al., 2021). Thus, the research demonstrates a causal relationship where digital academic supervision, by focusing on supervised teachers, can engage them in personal learning network activities related to their professional duties and responsibilities as educators, ultimately leading to their professional growth.

The phases of digital academic supervision and engagement in PLNs activities influence the enhancement of teacher professionalism. Initially, the pre-observation assessment entails collaborative efforts in shared values and vision, fostering a collective responsibility for enhancing student learning outcomes. This phase gains significance through its influence on the ethical and psychological growth of teachers, encompassing rights and responsibilities, spiritual values, self-assessment, humor expression, and learning actualization. Subsequently, the observation assessment involves recognizing learning characteristics. Supervisors facilitate teachers in utilizing digital media and tools, establishing connections, and promoting and fostering appropriate peer acknowledgment. This phase is pivotal for cultivating professional skills and advancing a teacher's career trajectory, encompassing curriculum and pedagogical knowledge, digital literacy, and peer relationships. Thirdly, solution provision prioritizes collaborative endeavors among principals, teachers, and external colleagues (such as other schools, researchers, and policymakers), with the aim of enhancing all facets of teacher professionalism, including professional skills, ethics, and career development. Lastly, reflection and follow-up prompt teachers to enhance their skills and foster collaboration and instructional feedback. These PLNs activities shape the implementation process, fostering active and continuous learning among educators through discussions and reflective discourse. Exploring and comprehending these components will yield valuable insights not only for teachers but also for principals, researchers, and policymakers.

Implementing digital academic supervision and fostering teacher professional development involves empowering teachers to explore innovations applicable in their classrooms. This is achieved by granting them the time and autonomy to develop alternative approaches. The diverse activities within PLNs facilitate this process for teachers. A meticulously crafted digital academic supervision program holds the potential to equip teachers with the skills needed to champion curriculum innovations essential in the digital era (Haleem et al., 2022; Nisa, 2023; Xie et al.,

2017).

Consistent with Groothijsen's (2019) findings, personal learning network mediation positively and significantly impacts digital academic supervision, contributing to teacher professionalism. These results align with previous findings indicating the significant influence of personal learning networks as mediators in such research (Emo, 2015). Therefore, the research highlights that digital academic supervision in secondary schools can enhance teacher professionalism and encourage teacher involvement in personal learning networks. Consequently, both teachers and stakeholders must adapt and acquire proficiency in utilizing technological resources, a crucial prerequisite for fostering employability. This necessity carries particular significance in secondary education, primarily catering to adults seeking to fulfill their educational needs.

5.5. Implication to educational policy

Based on research findings, the use of technology in educational supervision has significantly enhanced teacher professionalism. This has several implications for the education regulatory framework. First, robust data protection measures, including advanced encryption and strict access controls, are essential. These measures build trust among teachers, allowing them to focus on learning and teaching without concerns about data breaches (Reidenberg and Schaub, 2018). Regulations should also include data privacy and ethics training to strengthen professional integrity. Second, standardized tools and practices enable consistent and effective supervision, improving teaching quality. Policies should promote interoperable systems and standardized reporting tools to ensure all teachers have access to high-quality resources, enhancing professionalism across the education system. (Aksu and Canturk, 2015). Third, ongoing professional development through comprehensive and updated training programs is crucial. Regulations should mandate these programs and provide support structures like digital mentoring platforms and online resource hubs, ensuring teachers stay current with technological advancements. (Doukakis et al., 2019). Finally, certification programs that validate proficiency in digital supervision tools enhance teachers' professional credibility and career prospects (Amaya et al., 2018). Policies should support the development of tiered certification levels and provide incentives for certified individuals. Accrediting training providers ensure high-quality training and support professional development. In summary, integrating technology in educational supervision strengthens teacher professionalism by enhancing skills, ensuring ethical data handling, promoting standardized practices, and offering professional recognition and growth opportunities. The regulatory framework must support these aspects to foster continuous professional development and maintain high teaching standards.

6. Conclusion

The general objective of this study was to determine the effect of digital academic supervision and teachers' learning networks on improving teacher professionalism in secondary education in East Java Province, Indonesia. The initial findings of this research study underscore the influential role of digital academic

supervision (DAS) in shaping teachers' learning networks (PLNs), thereby contributing to the advancement of teacher professionalism. The application of digital academic supervision theory emerges as a novel approach, amplifying existing evidence supporting its efficacy. This study demonstrates how DAS optimizes teacher practice communities like PLNs, facilitating the exchange of information, acquisition, and development of various types of knowledge crucial for effective teaching in schools. Moreover, the study elucidates the intricate relationship between digital academic supervision and teacher PLNs, elucidating how leveraging digital tools throughout the academic supervision process enhances PLNs' ability to share a common vision, provide constructive feedback on instruction, recognize diverse learning characteristics, and foster collaboration. The study offers empirical evidence to expand the understanding of digital academic supervision's influence on teacher professionalism, particularly within Indonesian education. It underscores its efficacy in supporting teachers' preparedness and proficiency in utilizing information and communication technology (ICT) for enhanced teaching and learning experiences. Additionally, the research findings reinforce the significant influence of personal learning networks (PLNs) on teacher professionalism, highlighting shared values, constructive feedback, comprehensive understanding of the learning process, and active collaboration in fostering professional growth and development. The study aligns with previous research emphasizing the capacity of PLNs to facilitate profound learning, promote paradigm shifts in thinking and methodology, and enhance student achievement through collaborative systems within educational networks. Lastly, the research findings reveal a significant correlation between digital academic supervision and the mediating role of personal learning networks in enhancing teacher professionalism. The study underscores the causal relationship where DAS engages teachers in PLN activities related to their professional responsibilities, ultimately leading to their professional growth. This aligns with previous studies highlighting the significant influence of personal learning networks as mediators in enhancing teacher professionalism and underscores the potential of digital academic supervision in supporting teacher involvement in PLNs for continued professional development.

7. Limitation

It is critical to recognize the limitations of this study despite its encouraging contribution to the conceptualization and comprehension of the impact of digital academic supervision on enhancing teacher professionalism. First off, the conclusions of this study are restricted to causal relationships between variables because they are wholly correlational. Therefore, to better understand whether or not education can affect a group, it is crucial to carry out a relatively long-term study using an experimental research design. This will help to understand how pedagogical innovations, professional learning networks, and digital academic supervision can all improve teacher professionalism. Second, the fact that our study only looked at one district's excellent secondary school may limit the applicability of the results to other areas and educational institutions. Therefore, a more thorough investigation involving educators from different schools is required.

8. Implication

Investing in improving teacher professionalism is key to transforming the education system. For practitioners, integrating digital academic supervision (DAS) into supervision processes is a crucial step toward enhancing teacher professionalism. Institutions should provide comprehensive training and resources to supervisors and teachers alike on effectively utilizing digital tools to optimize the supervision process. Fostering personal learning networks (PLNs) among educators is paramount, with schools encouraged to create avenues for collaboration, reflection, and knowledge sharing through platforms like WhatsApp groups and virtual meetings. Prioritizing continuous professional development (CPD) initiatives tailored to teachers' needs and interests will further support their growth, focusing on leveraging digital tools, fostering PLNs, and promoting innovative teaching practices. Educational leaders should also cultivate a culture of innovation, recognizing and supporting teachers' experimentation with new pedagogical approaches and facilitating the sharing of successful practices within PLNs. Subsequently, in terms of future research, longitudinal studies tracking the impact of DAS on teacher professionalism and student outcomes over time could provide valuable insights into sustained effects. Comparative studies across different educational contexts could elucidate best practices and areas for improvement in DAS implementation. Qualitative and experimental research methods could delve into teachers' experiences with DAS and PLNs, uncovering perceptions, challenges, and strategies for leveraging digital tools effectively. Additionally, exploring the mediating factors that influence the relationship between DAS, PLNs, and teacher professionalism could inform the development of targeted interventions and support strategies. By addressing these implications for practice and future research, educators and researchers can continue advancing our understanding of DAS's role in promoting effective teaching and learning practices and enhancing teacher professionalism.

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Appendix

Table A1. Development of variable indicators.

Variables	Sub variables (indicators)	Sub indicators (items)
Digital academic supervision (DAS)	Pre-observation assessment	The teacher was interviewed online about the needs of teachers in teaching activities according to learning aspects (DAS1)
	Observation	Supervisor observes teacher and student behavior and interaction in class (DAS2)
		Supervisor employs digital tools for observation (DAS3)
	Solution provision	Supervisor sends analysis results via available online platforms or learning management systems (LMS) (DAS4)
	Reflection	Teachers are directed to evaluate their teaching performance in their classes through Google Forms and the learning management system (LMS) (DAS5)
	Follow-up	Supervisor encourages teachers to enhance their skills and foster collaboration through LMS and video conferences (DAS6)
		The supervisor summarizes the findings and collaboratively determines the next teaching plan (DAS7)
Teacher personal learning networks (PLNs)	Shared values and vision	As teachers, we share common values and vision to enhance the quality of teaching (PLN1)
		Improving student learning outcomes is a collective responsibility among teachers (PLN2)
	Feedback on instruction	I provide feedback on the implementation process of active and sustainable learning through reflective discussions and discourse (PLN3)
	Recognition of the characteristics of learning	As a teacher, I am active in making connections, promoting, and recognizing suitable colleagues with other teachers (PLN4)
	Collaboration	I collaborate closely with colleagues beyond our community (teachers, principals, researchers, and policymakers) to drive positive change (PLN5)
Teacher professionalism (TP)	Professional skill development	I master the theory of the subjects I teach (TP1)
		I delve into relevant methodological knowledge in addition to theoretical understanding (TP2)
		I possess curriculum knowledge and pedagogical content expertise in the field (TP3)
	Ethical and psychological development	I am aware of the rights and responsibilities both as a teacher and as an individual (TP4)
		I consider spirituality and universal values in school (TP5)
		I am capable of self-evaluating my performance and abilities as a teacher independently (TP6)
		I can actualize learning by involving humor with students (TP7)
	Career cycle development	I actively cultivate positive and warm relationships with peers (TP8)
		I am involved in professional organizations to share experiences to improve the quality of education (TP9)