

Does Digital Pedagogical Competence Strengthen Teachers' Professional Competence in Deep Learning? Evidence from SEM Analysis

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ARTICLE INFO	ABSTRACT
Article history Received Feb 28, 2026 Revised May 15, 2026 Accepted June 9, 2026	<p>Digital transformation in education requires teachers to combine professional competence with digital pedagogical competence to support meaningful learning. Deep learning characterized by conceptual understanding, critical thinking, and knowledge transfer has become a key goal of contemporary education, yet empirical evidence on the relationship among these competencies remains limited. This study examines the influence of digital pedagogical competence on teachers' professional competence, the effect of professional competence on students' deep learning, and the moderating role of digital pedagogical competence in this relationship. A quantitative approach using Partial Least Squares Structural Equation Modelling (PLS-SEM) was applied. Data were collected through questionnaires from 30 teachers in two senior high schools in Sintang Regency, Indonesia, selected through purposive sampling. Data analysis included measurement model evaluation (validity and reliability) and structural model testing using path coefficients, coefficient of determination (R^2), and bootstrapping. Digital pedagogical competence significantly influences teachers' professional competence ($\beta = 0.58, p < 0.001$). Professional competence also has a significant positive effect on students' deep learning ($\beta = 0.46, p < 0.001$). Furthermore, digital pedagogical competence significantly moderates the relationship between professional competence and deep learning ($\beta = 0.31, p = 0.008$). The model explains 34% of the variance in professional competence and 49% of the variance in deep learning. The findings highlight the importance of strengthening digital pedagogical competence to enhance teachers' professional competence and support deeper student learning.</p>
Keywords Digital pedagogical competence; Professional competence Deep learning Teacher competence PLS-SEM	

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I. Introduction

The transformation of education in the digital age has brought significant changes to school learning practices (Ivanova, 2025; Mateo-Guillen & Ocaña, 2025). Progress in information and communication technology has driven teachers to function not merely as transmitters of knowledge but also as facilitators capable of designing meaningful learning experiences for students (Tu & Hsu, 2025). In this context, a deep learning approach has become increasingly important because it emphasises deep conceptual understanding, critical thinking skills, and the ability to transfer knowledge across various real-life contexts (Morales-Vitela et al., 2025; Sepadi et al., 2025). Deep learning does not focus solely on mastering facts or memorisation, but on students' ability to analyse, evaluate, and apply knowledge reflectively (Akhtar, 2020; Mystakidis, 2021; Wei, 2023).

The application of deep learning in learning is greatly influenced by teachers' professional competence (Bogas, 2023; Narayanan & Arjun, 2024). Professional

competence reflects teachers' ability to master subject matter, understand the curriculum, and apply effective learning strategies (Duan, 2022; Kamoun-Chouk, 2025). Teachers who have a good command of the subject matter will be better able to explain concepts comprehensively and help students build meaningful understanding. In addition, understanding the curriculum allows teachers to align learning activities with expected learning objectives, making the learning process more focused and systematic (Dinçer, 2024; Zhou et al., 2023).

In addition, instructional strategies employed by teachers are crucial in promoting deep learning (Maksum et al., 2021). The implementation of diverse innovative pedagogical approaches can enhance students' involvement in learning activities as well as foster critical and reflective thinking abilities. Teachers who adapt learning strategies to students' needs tend to be more effective at creating a learning environment that supports knowledge exploration (Owan et al., 2023). Accordingly, teachers' professional competence serves as a crucial

determinant in ensuring the effective implementation of deep learning within classroom settings. On the other hand, the development of digital technology has expanded opportunities for teachers to develop more innovative learning practices (Fernández-Cruz et al., 2024). The incorporation of digital technology in educational processes facilitates the delivery of instructional content in a more interactive, adaptable, and contextually appropriate manner. (AlKasasbeh & Amawi, 2024; Korsager et al., 2023). Therefore, teachers need adequate digital pedagogical competencies to utilise technology effectively in the learning process (Utami et al., 2025). These competencies include the ability to integrate technology into learning activities, design digital-based learning, and utilise technology to conduct learning assessments.

Digital pedagogical competence is not only about the technical ability to use technological devices, but also about the pedagogical ability to design meaningful learning experiences through technology (Burns et al., 2020; Miguel-Revilla et al., 2020). Teachers with strong digital pedagogical competence can select and use a range of digital learning resources effectively to support learning objectives (Tadeco & Fitrasari, 2024). In addition, the use of digital platforms for assessment allows teachers to provide faster, more accurate feedback to students, enabling learning process to proceed more effectively (Rawat et al., 2024). Although various studies have highlighted the importance of teachers' professional competencies and the use of technology in education, the relationship between digital pedagogical competencies and teachers' professional competencies in supporting deep learning remains underexplored (Bentri et al., 2025). Some studies have focused more on the direct influence of technology on student learning outcomes, while the role of digital pedagogical competencies in strengthening the relationship between teachers' professional competencies and deep learning has not been explored empirically (Tarraga-Minguez et al., 2021; Zhang et al., 2026). This condition indicates a research gap that warrants further examination.

Moreover, studies employing the Structural Equation Modelling (SEM) technique to examine the associations between digital pedagogical competence, teacher professional competence, and deep learning are still scarce, particularly within secondary education settings in rural regions. A more comprehensive understanding of the relationship between these variables is important to provide an empirical basis for the development of teacher competencies in the digital age. Thus, this study seeks to examine how digital pedagogical competencies influence teachers' professional competencies and how these competencies shape deep learning among students.

Drawing on this context, the present study seeks to examine the effect of digital pedagogical competence on teachers' professional competence as well as the impact of teachers' professional competence on students' deep

learning. In addition, this study also aims to examine whether digital pedagogical competence can strengthen the relationship between teachers' professional competence and deep learning. In line with this objective, this study proposes three main hypotheses, namely:

H1: Digital pedagogical competence positively influences teachers' professional competence.

H2: Teachers' professional competence positively influences students' deep learning.

H3: Digital pedagogical competence strengthens the relationship between teachers' professional competence and deep learning.

II. Method

A. Research Design

This research adopted a quantitative methodology to investigate the interrelationships among digital pedagogical competence, teachers' professional competence, and students' deep learning outcomes. (Alford & Teater, 2025). The research model was evaluated through Structural Equation Modeling (SEM) employing the Partial Least Squares (PLS) technique. SEM-PLS was selected because it allows simultaneous examination of multiple relationships among latent variables and is suitable for predictive research models with relatively small sample sizes (Effendi et al., 2025; Muhibbin et al., 2023).

The application of PLS-SEM in this research was further justified by its aim to analyze a prediction-focused model that incorporates both direct and moderating relationships among latent variables. However, considering the relatively small sample size, the findings of this study should be interpreted cautiously as preliminary empirical evidence rather than definitive causal conclusions. To reduce the risk of overinterpretation, the analysis focused not only on statistical significance but also on the direction, magnitude, and consistency of the path coefficients.

The study investigated whether digital pedagogical competence influences teachers' professional competence and strengthens the relationship between professional competence and deep learning. The proposed structural model included three latent variables: digital pedagogical competence, teachers' professional competence, and deep learning. Each latent variable was measured reflectively using six observed indicators, resulting in a total of 18 questionnaire items.

B. Participants and Sampling

The study involved 30 educators from two senior secondary schools located in Sintang Regency, Indonesia. These teachers were actively involved in classroom instruction and had experience integrating teaching strategies within the school curriculum. The study

employed purposive sampling as the sampling method, whereby participants were chosen according to their relevance to the objectives of the research. Teachers were chosen because they play a central role in implementing instructional practices, integrating digital technology into teaching, and facilitating students' deep learning processes.

All participating teachers had teaching responsibilities in their respective schools and were considered capable of providing valid responses regarding their professional competence, digital pedagogical competence, and instructional practices that promote deep learning.

To ensure the sufficiency of the sample size, an a priori power analysis was performed using G*Power prior to conducting the primary analysis. The computation was grounded in a multiple regression model with two predictor variables, assuming a medium to large expected effect size, a significance threshold of 0.05, and a statistical power of 0.80. The outcomes demonstrated that the minimum required sample size was approximately equivalent to the number of respondents included in the study. Accordingly, the sample size was deemed adequate for an initial PLS SEM examination, although its capacity for broad generalization remains constrained.

Beyond the power analysis, the sample size determination was also assessed using the minimum sample size principle frequently employed in PLS-SEM, which is based on identifying the largest number of structural relationships pointing toward a latent variable. In this model, the most complex endogenous construct was deep learning, which received two predictors: teachers' professional competence and the interaction term involving digital pedagogical competence. Based on this criterion, the sample size of 30 met the minimum requirement for exploratory PLS-SEM estimation. Nevertheless, because the model involved 18 indicators and three latent constructs, the limited sample size is acknowledged as a methodological limitation. Future studies are encouraged to replicate this model using a larger and more diverse sample.

C. Instruments

Data were obtained through a structured survey instrument developed to assess the three variables within the research framework, namely teachers' professional competence, digital pedagogical competence, and deep learning. Each indicator was evaluated using a five-point Likert scale, where responses ranged from 1 indicating strongly disagree to 5 indicating strongly agree (Kusmaryono et al., 2022). The instrument consisted of 18 items adapted from theoretical constructs related to teacher competence, digital pedagogy, and deep learning practices. Each construct was defined operationally using multiple indicators, as presented in Table 1.

Table 1. Research Instrument

Variable	Indicator	Item Statement
Professional Competence	Subject mastery	I have a strong understanding of the subject matter that I teach. I am able to explain complex concepts in my subject clearly to students.
	Curriculum understanding	I understand the learning objectives and competencies outlined in the curriculum. I align my teaching activities with curriculum standards and learning outcomes.
	Instructional strategy	I use a variety of teaching strategies to support students' learning. I adapt my instructional methods to meet students' learning needs.
Digital Pedagogical Competence	Technology integration	I integrate digital technologies into my teaching to support learning activities. I use digital tools to enhance students' engagement in learning. I design learning activities that effectively incorporate digital technology.
	Digital learning design	I select appropriate digital resources to support learning objectives. I use digital platforms to assess students' learning outcomes. I provide feedback to students through digital assessment tools.
Deep Learning	Digital assessment	I use digital platforms to assess students' learning outcomes. I provide feedback to students through digital assessment tools.
	Critical thinking	I encourage students to analyze and evaluate information during learning activities. I ask students to explain the reasoning behind their answers.
	Conceptual understanding	I design learning activities that help students understand concepts deeply rather than memorize facts. I encourage students to connect new knowledge with prior understanding.
	Knowledge transfer	I encourage students to apply what they learn to real-life situations. I provide learning tasks that require students to use knowledge in new contexts.

D. Data Collection Procedures

Data collection was conducted through a questionnaire survey administered to teachers in the two participating senior high schools in Sintang Regency. The questionnaires were distributed directly to the respondents and completed voluntarily. Prior to data collection, participants were briefed regarding the objectives of the study and were guaranteed that their responses would be kept confidential and utilized exclusively for research purposes. The completed questionnaires were then compiled and coded for statistical analysis.

E. Data Analysis

The gathered data were examined through Partial Least Squares Structural Equation Modeling (PLS-SEM) utilizing SmartPLS software. This method was selected because it is appropriate for analyzing relationships among latent variables and is suitable for studies with relatively small sample sizes.

Data analysis was performed through a two-step procedure. Initially, the measurement model was examined to determine construct reliability and validity by applying indicator loadings, Cronbach's Alpha, Composite Reliability, and Average Variance Extracted (AVE). Subsequently, the structural model was evaluated to test the proposed hypotheses by assessing path coefficients (β), the coefficient of determination (R^2), and bootstrapping outputs to establish the statistical significance of the relationships.

III. Results and Discussion

A. Measurement Model Evaluation

Data analysis in this research employed Partial Least Squares Structural Equation Modeling (PLS-SEM) to examine the relationships among latent variables within the proposed model. Prior to assessing the structural associations between variables, the measurement model was first evaluated to confirm that the indicators demonstrate sufficient validity and reliability in representing the constructs under investigation. The assessment of the measurement model involved testing convergent validity through outer loadings, alongside examining construct reliability and internal consistency.

To evaluate convergent validity, the analysis was performed by inspecting the outer loading values of each indicator in relation to its corresponding latent construct. A higher outer loading value reflects a stronger capacity of an indicator to represent the intended construct. The outcomes of the outer loading assessment for all indicators in this study are reported in Table 2.

Table 2. Outer Loadings of Indicators

Construct	Indicator	Outer Loading
Professional Competence	PC1	0.84
	PC2	0.86
	PC3	0.82
	PC4	0.87
	PC5	0.85
	PC6	0.83
Digital Pedagogical Competence	DPC1	0.83
	DPC2	0.85
	DPC3	0.86
	DPC4	0.84
	CPD5	0.82
	DPC6	0.83
Deep Learning	DL1	0.86
	DL2	0.87
	DL3	0.85
	DL4	0.84
	DL5	0.83
	DL6	0.86

Based on the results shown in Table 1, all indicators have an outer loading value above 0.70, indicating that each indicator makes a strong contribution to representing the latent construct being measured. The high outer loading values indicate that these indicators adequately explain the construct's variance and have strong correlations with the constructs they represent. Thus, all indicators in this study meet the criteria for convergent validity, making them suitable for use in structural model analysis at a later stage.

After confirming convergent validity via outer loadings, the subsequent stage involves assessing construct reliability and internal consistency for each latent variable within the research framework. This evaluation employed several standard statistical indicators in Partial Least Squares Structural Equation Modeling, including Cronbach's Alpha, Composite Reliability (CR), and Average Variance Extracted (AVE). Cronbach's Alpha and Composite Reliability are utilized to determine the internal consistency of each construct, whereas AVE serves to verify that the construct sufficiently accounts for the variance of its indicators. The outcomes of the reliability and convergent validity assessments are reported in Table 3.

Table 3. Construct Reliability and Convergent Validity

Construct	Cronbach Alpha	Composite Reliability	AVE
Professional Competence	0.91	0.93	0.69
Digital Pedagogical Competence	0.90	0.92	0.67
Deep Learning	0.92	0.94	0.71

The analytical outcomes presented in Table 2 demonstrate that all constructs within the research framework satisfy the required thresholds for reliability and convergent validity in PLS SEM analysis. The Cronbach's Alpha values ranging from 0.90 to 0.92 reflect strong internal consistency among indicators representing the same latent construct. Moreover, Composite Reliability scores exceeding 0.90 confirm that each construct possesses a high level of reliability in accounting for the variance of its indicators. In addition, the Average Variance Extracted values between 0.67 and 0.71 indicate that more than half of the variance in the indicators is successfully captured by each construct, thereby fulfilling the criteria for convergent validity. Accordingly, it can be inferred that all constructs demonstrate robust internal consistency and satisfactory convergent validity, confirming that the measurement model is appropriate for subsequent structural model evaluation.

B. Structural Model Evaluation

Once the measurement model satisfies the required validity and reliability standards, the subsequent step involves assessing the structural model to examine the hypothesized causal relationships among the latent variables specified in the research framework. This evaluation is carried out by analyzing the path coefficient, which indicates the strength and direction of the relationship between variables, thereby providing an overview of each variable's contribution to explaining the model's structural relationships.

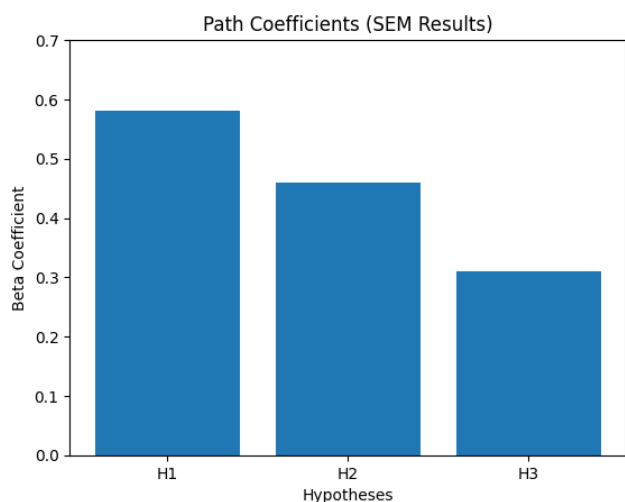


Fig. 1. Structural Model and Path Coefficients

Figure 1 presents the path coefficients associated with each relationship within the proposed research framework. The findings indicate that digital pedagogical competence exerts a positive effect on professional competence ($\beta = 0.58$), representing the most substantial influence within the model. Furthermore, professional competence demonstrates a positive relationship with deep learning ($\beta = 0.46$), suggesting that higher levels of teacher professional competence are linked to enhanced student

deep learning outcomes. In addition, digital pedagogical competence functions as a moderating variable in the relationship between professional competence and deep learning ($\beta = 0.31$), indicating that it amplifies the effect of professional competence on deep learning. Collectively, these results confirm that all hypothesized relationships are positively directed and provide preliminary empirical support for the proposed model.

After the interrelationships among the constructs in the structural model are illustrated in Figure 1, the subsequent stage involves assessing their statistical significance through the bootstrapping technique within the PLS-SEM framework. This procedure is conducted to ascertain whether the associations between the latent variables in the proposed model are statistically significant and to examine the extent to which the formulated hypotheses are supported. The outcomes of this analysis, comprising the path coefficient (β), t-statistic, and p-value, are reported in Table 4.

Table 4. Path Coefficient Results

Hypothesis	Relationships	β	t-value	p-value	Results
H1	Digital Pedagogical Competence → Professional Competence	0.58	4.37	0.000	Supported
H2	Professional Competence → Deep Learning	0.46	3.91	0.000	Supported
H3	Digital Pedagogical Competence × Professional Competence → Deep Learning	0.31	2.68	0.008	Supported

The analysis showed that digital pedagogical competence had a positive and significant influence on teachers' professional competence ($\beta = 0.58$, $p < 0.001$). These findings show that teachers who can integrate digital technology into the learning process tend to have higher professional competence.

In addition, teachers' professional competence also has a positive and significant effect on students' deep learning ($\beta = 0.46$, $p < 0.001$). This shows that teachers' professional competence plays an important role in fostering learning that encourages deep conceptual understanding, critical thinking, and knowledge transfer to real-world situations.

C. Coefficient of Determination

Beyond examining the significance of inter-variable relationships through path coefficients, structural model evaluation in PLS-SEM also involves the assessment of the coefficient of determination (R^2), which reflects the model's explanatory power over the variance of endogenous constructs. The R^2 statistic demonstrates the degree to which exogenous variables within the model account for variations in the endogenous variables.

Figure 2 presents the coefficient of determination for the endogenous constructs within the proposed research model. The findings indicate that Professional Competence yields an R^2 value of 0.34, demonstrating that 34 percent of the variation in teachers' professional competence is accounted for by Digital Pedagogical Competence. In addition, Deep Learning shows an R^2 value of 0.49, indicating that 49 percent of the variance in students' deep learning is jointly explained by Professional Competence and Digital Pedagogical Competence within the model framework.

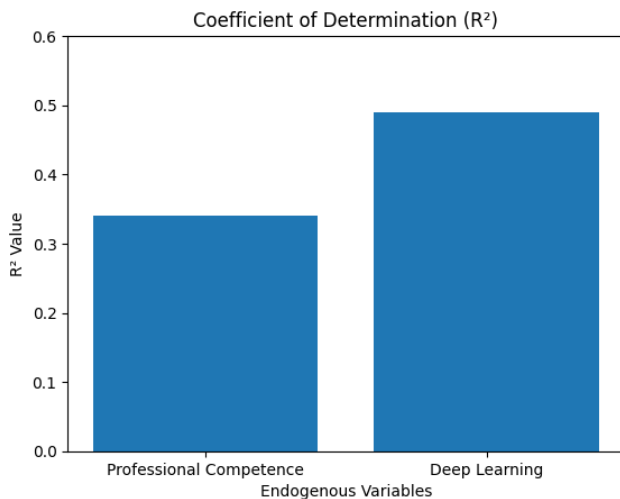


Fig. 2. Coefficient of Determination (R^2)

To provide a more systematic interpretation of the value of the determination coefficient, the results of the R^2 analysis are presented in detail in Table 5.

Table 5. R-Square Values

Dependent Variable	R^2	Interpretation
Professional Competence	0.34	Moderate
Deep Learning	0.49	Moderate

An R^2 value of 0.34 indicates that 34% of the variation in teachers' professional competence is explained by digital pedagogical competence. Meanwhile, an R^2 value of 0.49 indicates that nearly 49% of students' deep learning variation can be explained by teachers' professional and digital pedagogical competence. This value indicates that the model has moderate explanatory power, a finding commonly observed in educational research.

D. Moderation Effect Analysis

Beyond the assessment of direct associations within the structural model, this study further investigates the moderating function of digital pedagogical competence in shaping the relationship between professional competence and deep learning outcomes. The moderation analysis was conducted within the PLS-SEM framework by forming an interaction term between digital pedagogical competence and professional competence to test Hypothesis 3, namely whether digital pedagogical competence strengthens or weakens the influence of teachers' professional competence on students' deep learning.

Figure 3 illustrates the interaction pattern between professional competence and deep learning across varying levels of digital pedagogical competence. The visualization indicates that the association between professional competence and deep learning intensifies as digital pedagogical competence rises, as reflected in the increasingly steep slope of the line. This suggests that teachers' capacity to integrate digital technologies into instructional practices strengthens the effect of professional competence in fostering deeper learning outcomes.

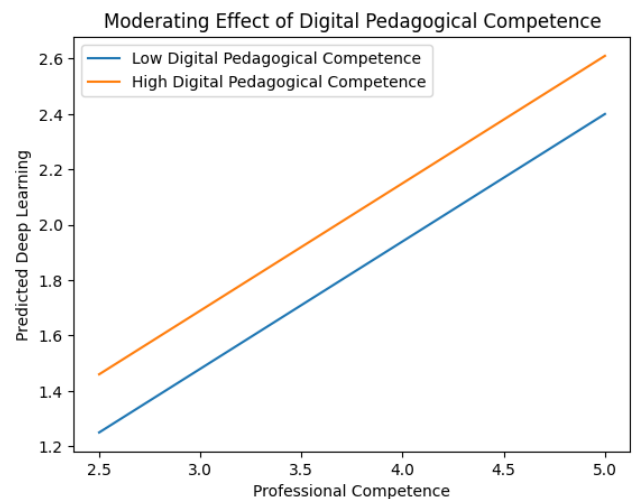


Fig. 3. Moderating Effect of Digital Pedagogical Competence

To ascertain the significance of the moderation effect, the results of the interaction term analysis are presented in Table 6.

Table 6. Moderation Effect

Relationship	β	t-value	p-value
DPC \times Professional Competence \rightarrow Deep Learning	0.31	2.68	0.008

Based on the results in Table 5, the interaction between digital pedagogical competence and professional competence had a path coefficient of $\beta = 0.31$, with a t-value of 2.68 and a p-value of 0.008, indicating a positive,

significant moderation effect. These findings indicate that digital pedagogical competence significantly strengthens the influence of professional competence on deep learning, so that the higher the teacher's ability to utilize digital technology in learning, the stronger the contribution of professional competence in encouraging deeper learning in students.

Empirical findings from this study demonstrate significant interconnections among digital pedagogical competence, teachers' professional competence, and students' deep learning within the context of digital education. Structural model analysis confirms that all hypothesized relationships are statistically validated, suggesting that teacher competence plays a crucial role in facilitating meaningful and engaging learning experiences. These findings confirm that the transformation of technology-based education requires teachers not only to have strong mastery of the material but also pedagogical skills to effectively integrate technology into the learning process (Fernández-Cruz et al., 2024; Mateo-Guillen & Ocaña, 2025).

The initial results demonstrate that digital pedagogical competence exerts a significant and positive influence on teachers' professional competence. This suggests that educators who effectively incorporate digital technologies into their pedagogical practices generally exhibit stronger professional competence. This outcome is strongly supported by established theoretical frameworks, particularly the Technological Pedagogical Content Knowledge (TPACK) model (Mishra & Koehler, 2006) and the European Digital Competence Framework for Educators (DigCompEdu; Redecker, 2017), both of which posit that effective teaching in digital environments requires the integration of technological, pedagogical, and content knowledge. Within the TPACK framework, teachers who develop digital pedagogical competence are better equipped to select appropriate technological tools that align with their pedagogical goals, thereby enriching their overall instructional repertoire. Similarly, the DigCompEdu framework conceptualizes digital competence as comprising not merely technical proficiency but also the capacity to facilitate learner-centered experiences, assess digitally, and empower learners through technology. Digital pedagogical competencies thus allow teachers to design innovative learning activities, select relevant digital learning resources, and facilitate more dynamic learning interactions (Bentri et al., 2025; Miguel-Revilla et al., 2020). Thus, mastery of technology not only improves teachers' technical skills but also strengthens their ability to design learning strategies that align with curriculum goals and student needs (Burns et al., 2020; Dinçer, 2024). These findings align with previous research indicating that integrating technology into learning can improve teachers' professional capacity and the quality of classroom teaching practices (Taylor, 2023).

This relationship is particularly significant in the rural context of Sintang Regency, where teachers face additional challenges in accessing professional development opportunities and educational resources. In such settings, digital pedagogical competence may serve as a compensatory mechanism, enabling teachers to overcome geographic and infrastructural constraints by leveraging technology to access updated curriculum materials, collaborate with peers remotely, and deliver more engaging instruction (Sepadi et al., 2025). The present findings therefore underscore the strategic importance of investing in digital literacy training for teachers in underserved rural areas as a pathway to elevating overall professional standards.

The second finding shows that teachers' professional competence positively and significantly influences students' deep learning. This shows that teachers' professional competence plays an important role in fostering a learning process oriented towards conceptual understanding, critical thinking, and knowledge transfer skills. Teachers who have a strong mastery of the material and an effective pedagogical strategy are better able to guide students to engage in high-level cognitive processes. In this context, learning no longer focuses solely on memorization, but on students' ability to analyze, evaluate, and apply knowledge across a variety of real-world situations (Morales-Vitela et al., 2025; Mystakidis, 2021). These findings are consistent with research confirming that teacher competence is a key factor in improving the quality of learning and fostering meaningful learning (Bogas, 2023; Zhou et al., 2023).

The underlying mechanism through which professional competence promotes deep learning can be explained by the fact that teachers who deeply understand their subject matter are better positioned to design cognitively challenging tasks, ask higher-order questions, and scaffold students' thinking toward concept integration rather than surface-level recall. Within the DigCompEdu framework, this corresponds to the domain of "facilitating learners' digital competence," where teachers leverage their pedagogical expertise to create situations that demand reflection, analysis, and synthesis. In the rural school context of Sintang Regency, where students may have limited exposure to enriched learning environments, the role of the teacher's professional competence becomes even more pronounced as a primary driver of instructional quality and deep engagement with content.

Furthermore, the results of the moderation analysis show that digital pedagogical competence strengthens the relationship between teachers' professional competence and deep learning (Barkoczi & Roman, 2025; Tarraga-Minguez et al., 2021). These findings show that the influence of professional competence on deep learning becomes stronger when teachers have a high level of digital pedagogic competence. In other words, digital competencies not only contribute directly to learning

effectiveness but also enhance the ability of professional competencies to produce more immersive learning experiences. Teachers who can combine mastery of content, pedagogical strategies, and digital technology can create a more interactive, collaborative, and flexible learning environment. The use of digital technology enables teachers to visualize complex concepts, facilitate student collaboration, and provide quick feedback, thereby supporting the knowledge construction process more effectively (González-Medina et al., 2025; Saure et al., 2025).

The substantive meaning of this moderating effect warrants closer examination. A moderation coefficient of $\beta = 0.31$ indicates that for each unit increase in digital pedagogical competence, the effect of professional competence on deep learning increases by 0.31 standard deviations. This implies that professional competence alone, while important, does not fully translate into deep learning outcomes unless it is activated and amplified by digital pedagogical skills. The interaction can be interpreted through the TPACK lens: when teachers possess not only content and pedagogical knowledge but also the technological knowledge to deploy these skills in digital environments, the combined effect exceeds what either competence could achieve independently. In practical terms, a teacher with strong subject mastery who can also use simulation tools, digital concept maps, or collaborative online platforms is better equipped to bring abstract concepts to life and prompt students' higher-order thinking. This synergistic effect is especially meaningful in rural contexts such as Sintang Regency, where digital tools may represent one of the few available avenues for enriching the learning environment beyond traditional textbook instruction (Korsager et al., 2023; Sepadi et al., 2025). The finding thus carries important implications for teacher education policy: developing professional competence and digital pedagogical competence in an integrated rather than siloed manner is likely to yield greater gains in student learning depth.

In addition, the value of the determination coefficient (R^2) in this study showed that the proposed model had a moderate explanatory ability, where digital pedagogical competence explained some of the variances of teachers' professional competence, while the combination of professional competence and digital pedagogical competence explained almost half of students' deep learning variances (Agustini et al., 2019; Niiniluoto, 2022; Putra et al., 2025). This shows that these two competencies are important factors in explaining the creation of deep learning, although there are still other factors that also have the potential to affect the learning process, such as student learning motivation, support of the school environment, and other pedagogical characteristics (Korsager et al., 2023; Wei, 2023). Thus, teacher competence remains a central component in efforts to improve the quality of learning in the digital education era.

Overall, the findings of this study confirm the importance of strengthening digital pedagogical competencies as an integral part of teacher professional development. In the context of rapid developments in educational technology, teachers are required not only to master the learning content but also to integrate technology strategically into the teaching process. Therefore, educational institutions and policymakers need to provide support through ongoing professional development programs that emphasize the integration of professional and digital pedagogical competencies (Yadav, 2024). These efforts can help create a more innovative, interactive, and student-centered learning environment to encourage the development of critical thinking skills, conceptual understanding, and meaningful application of knowledge in students.

IV. Conclusion

This study examined the relationships between digital pedagogical competence and teachers' professional competence in deep learning within the context of digital-era education. Using a PLS-SEM approach with data collected from high school teachers, the analysis confirmed that the measurement model met the required standards of validity and reliability, indicating that the constructs were measured consistently. The structural analysis further revealed that digital pedagogical competence significantly contributes to strengthening teachers' professional competence, indicating that the ability to design and implement technology-supported learning plays an important role in enhancing teachers' instructional capacity. In addition, professional competence was found to positively influence students' deep learning, highlighting the importance of teachers' mastery of subject matter, understanding of the curriculum, and instructional strategies in facilitating deeper conceptual understanding and higher-order thinking. Beyond these direct relationships, the findings also demonstrate that digital pedagogical competence amplifies the influence of professional competence on deep learning. This suggests that when teachers possess strong digital pedagogical skills, their professional expertise becomes more effective in fostering learning environments that promote critical thinking, conceptual engagement, and knowledge application. Overall, the study highlights that improving educational quality in the digital era requires not only strengthening teachers' professional competence but also developing their capacity to integrate technology pedagogically. These results emphasize the importance of continuous professional development programs that integrate pedagogical, professional, and digital competencies to support more meaningful and transformative learning experiences for students.

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