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The Relationship Between Digital Literacy, TPACK Competence, and Geography Teachers' Teaching Performance in Gorontalo Province

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Abstract

The transformation of education in the era of artificial intelligence demands that teachers possess two complementary digital competencies: digital literacy and Technological Pedagogical and Content Knowledge (TPACK). However, the relationship between these competencies and geography teachers' teaching performance, including the interaction dynamics between them within a single analytical model, has rarely been empirically explored. This study aims to analyze the relationship between digital literacy and TPACK competence with the teaching performance of geography teachers in senior high schools (SMA/MA) in Gorontalo Province, both partially and simultaneously. A quantitative associative approach with a multiple correlation and multiple regression design was employed. The population comprised all active geography teachers in Gorontalo Province during the 2025/2026 academic year (N = 98), and population-based sampling approach yielded 70 valid respondents. Data were collected through a Likert scale questionnaire and analyzed using Pearson Product Moment correlation and multiple linear regression. Results indicate that: (1) digital literacy has a significant positive correlation with teaching performance ($r = 0.484$; $p < 0.001$); (2) TPACK competence shows a stronger correlation with teaching performance ($r = 0.532$; $p < 0.001$); and (3) simultaneously, both variables significantly contribute to teaching performance ($F = 14.687$; $p < 0.001$; $R^2 = 0.305$). A critical finding reveals that within the multiple regression model, the high correlation between digital literacy and TPACK ($r = 0.716$) renders the partial contribution of digital literacy non-significant ($p = 0.151$). This pattern indicates that TPACK may capture part of the shared variance between digital literacy and teaching performance.

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However, whether TPACK functions as a mediator should be examined in future studies using formal mediation analysis.

Keywords: Digital Literacy, TPACK, Teaching Performance, Geography Teacher

INTRODUCTION

The quality of national education is inseparable from the quality of teachers' instructional practice. In the modern learning landscape, teachers are no longer mere transmitters of knowledge; they are designers of adaptive, evidence-based, and technology-responsive learning experiences (Huda, 2022). This demand has intensified with the accelerating digital transformation of Indonesia's education system, reflected in the school digitalization policy under the Merdeka Belajar framework and the mandate for technology integration in Ministerial Regulation No. 22 of 2016 on Learning Standards. This paradigm shift repositions teachers' digital competence not as an added value, but as a fundamental professional requirement.

The growing penetration of artificial intelligence (AI) in educational ecosystems adds further complexity to this challenge. Adaptive learning platforms, student data analytics, AI-assisted content creation, and geospatial technologies such as Geographic Information Systems (GIS) and satellite imagery in geography instruction all demand teachers who go beyond basic technological proficiency and are capable of integrating technology into meaningful pedagogical practice. It is within this context that two competency constructs become particularly relevant: digital literacy and Technological Pedagogical and Content Knowledge (TPACK).

Digital literacy refers to the multidimensional ability to access, evaluate, manage, and create information through digital platforms critically and responsibly (UNESCO, 2025). In the context of education, Liu & Xu (2025) note that teachers' digital literacy has evolved from a basic operational skillset into a multifaceted system that encompasses technology integration, data-driven thinking, ethical awareness, and transformational leadership. For geography teachers, digital literacy carries particular relevance, as the discipline is deeply reliant on spatial data, cartographic visualization, and dynamic geospatial information about continuously evolving earth phenomena. Teachers with strong digital literacy can leverage interactive maps, satellite imagery, and global geospatial databases to deliver contextually grounded, data-driven instruction (Widiyatmoko et al., 2024).

TPACK, as conceptualized by Mishra & Koehler (2006), offers a more integrative theoretical framework. As Gonzalez & Bravo (2023) describe, TPACK is an important framework for the proper

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integration of technologies in the classroom, in which technological knowledge (TK) interacts with pedagogical knowledge (PK), content knowledge (CK), and pedagogical content knowledge (PCK), giving rise to composite constructs such as TPK, TCK, and TPACK that coordinate these knowledge domains to facilitate student learning through ICT. Since its original formulation, the TPACK framework has undergone significant theoretical development. Petko et al. (2025) proposed an updated model that incorporates Contextual Knowledge (XK) as an eighth distinct knowledge domain, arguing that TPACK "should be seen as a dynamic process rather than a static construct" that develops and is continuously reapplied across practical teaching contexts. This reconceptualization is particularly pertinent to the present study, which examines TPACK competence in the distinct contextual conditions of Eastern Indonesia. Within this integrative framework, TPACK goes beyond the ability to operate technology, capturing the capacity to understand how specific technologies can most effectively be combined with particular pedagogical strategies and subject matter content. In the context of geography education, TPACK encompasses a teacher's ability to determine when and how tools such as Google Earth, GIS applications, or other digital platforms are most appropriately deployed to help students comprehend geospheric concepts, develop spatial thinking, and analyze real-world geographic phenomena. The mere presence of technology in the classroom does not guarantee instructional improvement; what matters is the depth of the teacher's understanding of how to integrate technology within specific pedagogical and content contexts (Mishra & Koehler, 2006).

Despite the extensive scholarly attention both constructs have received, the relationship between digital literacy, TPACK, and teaching performance has not been comprehensively examined, particularly as an integrated analytical model. Existing studies tend to investigate these variables in isolation or within the context of broader subject areas such as science, mathematics, or social studies, leaving the interplay between them in geography teachers' instructional practice inadequately understood (Listiqowati, 2024). Furthermore, the majority of relevant research has been conducted in Java and Sumatra, while the educational context of Eastern Indonesia, with its distinct infrastructure, teacher distribution, and technology access characteristics, remains virtually absent from the empirical literature.

This research gap becomes more pronounced when examining field conditions in Gorontalo Province. A preliminary observation of 21 geography teachers at senior high schools in the province revealed an average TPACK score of 3.91 on a 1–5 scale, lower than both digital literacy (4.06) and teaching performance (4.10). This discrepancy suggests a gap between teachers' general capacity to access and use technology and their ability to integrate technology

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pedagogically within geography-specific content. Initial interviews further revealed that technology use among geography teachers in Gorontalo is largely confined to conventional presentation media, with interactive digital maps, GIS applications, and other digital platforms remaining largely untapped in classroom practice. A comparable pattern was documented by Nofrion et al. (2018) in a study of geography teachers in Solok Regency, West Sumatra, which found TPACK competence at a moderate level with the primary weakness in technology integration during instruction.

Judijanto (2024) identified a significant correlation between digital literacy and instructional quality among teachers across various levels; however, that study neither focused specifically on geography teachers nor incorporated TPACK as a variable. Aliman et al. (2025) confirmed that TPACK is a critical indicator of geography teachers' readiness for 21st-century learning, yet their study targeted pre-service teacher candidates rather than practicing teachers. Sugiarto & Dewantara (2021) found that social studies teachers with higher digital literacy tend to be more adaptive in their instructional approaches, but did not include TPACK in their analysis.

From this literature mapping, at least three research gaps are identifiable. First, no study has simultaneously integrated digital literacy and TPACK as predictors of geography teachers' teaching performance within a single statistical model. Second, the interaction between digital literacy and TPACK, including the possibility that one variable mediates or absorbs the effect of the other, has not been empirically examined. Third, the geographic context of existing research does not represent the conditions of geography teachers in Eastern Indonesia, particularly Gorontalo, which has its own distinct characteristics in terms of technology access and professional development capacity.

This study addresses all three gaps. Employing a quantitative correlational design and multiple regression analysis, it not only measures the strength of the relationship between each variable and teaching performance but also reveals how the two predictors interact within a simultaneous model, an aspect consistently overlooked in comparable research. The novelty of this study rests on three dimensions: (1) subject specificity, targeting the entire population of active geography teachers in a single province, with data obtained from 70 of 98 teachers (71.4%), representing a high response rate for an online survey in a geographically dispersed region; (2) the analysis of interaction between two digital predictors in a multiple regression model, enabling the identification of a conceptually meaningful multicollinearity phenomenon; and (3) the temporal context of data collection during the 2025/2026 academic year, situating the findings within an educational landscape actively adapting to the widespread emergence of AI.

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Based on the foregoing, this study addresses three primary research questions: (1) Is there a significant relationship between digital literacy and the teaching performance of geography teachers at SMA/MA in Gorontalo Province? (2) Is there a significant relationship between TPACK competence and the teaching performance of geography teachers at SMA/MA in Gorontalo Province? (3) Do digital literacy and TPACK competence simultaneously have a significant relationship with the teaching performance of geography teachers at SMA/MA in Gorontalo Province?

METHODS

This study employed a quantitative approach with an associative correlational design, selected because the primary objective was to analyze the strength and direction of relationships among variables without manipulating research conditions (Ramadhani & Albina, 2025). Multiple correlation and multiple regression analyses were used to examine the relationships between digital literacy (X_1) and TPACK competence (X_2) with teaching performance (Y), both partially and simultaneously.

Population and Sample

The study population comprised all active geography teachers at SMA/MA in Gorontalo Province during the 2025/2026 academic year, distributed across six regencies and municipalities with a total of 98 individuals. Given the manageable population size, population-based sampling approach was applied as the intended sampling strategy by inviting all 98 geography teachers in the population to participate in the study. However, the final analyzable sample consisted of 70 teachers who voluntarily completed the questionnaire, representing a response rate of 71.4%. To assess potential non-response bias, the distribution of respondents across regencies was compared with the population distribution. No systematic pattern of non-response was identified based on geographic location or school type, suggesting that the achieved sample is reasonably representative of the target population.

Instrumentation

Data were collected using a five-point Likert scale questionnaire (1 = strongly disagree to 5 = strongly agree) comprising three sections corresponding to the study variables. The digital literacy instrument (X_1) was developed based on six indicators adapted from the UNESCO (2025) digital literacy framework, covering the use of digital technology in instruction, evaluation of

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digital learning resources, information management, content development, digital communication, and digital ethics and safety. The indicators were further contextualized to reflect the specific demands of geography instruction, including the use of spatial data platforms and geospatial tools prevalent in the discipline. The instrument originally contained 23 items, of which 20 were retained following validity testing.

The TPACK instrument (X_2) was constructed based on the Mishra & Koehler (2006) framework, operationalized through five indicators adapted to the geography instructional context: integrated lesson design, development of technology-based learning activities, facilitation of spatial analysis, evaluation of technology effectiveness, and modification of instructional plans. Of the original 21 items, 16 were confirmed valid. The teaching performance instrument (Y) was developed in reference to Minister of State Apparatus Empowerment Regulation No. 16 of 2009 and nationally established teacher performance indicators, encompassing three dimensions: lesson planning, instructional delivery, and learning evaluation, with all 14 items confirmed valid. Teaching performance in this study refers to teachers' self-perceived teaching performance as measured through a self-report questionnaire.

Each instrument underwent validity and reliability testing prior to data collection. Items that did not meet the validity threshold ($r < 0.235$) were excluded, resulting in a reduction from the original item pool. The final structure of each instrument, including the number of valid items retained and the corresponding Cronbach's Alpha coefficients, is presented in Table 1.

Table 1. Instrument Structure and Reliability

Variable	Indicators	Initial Items	Valid Items	Cronbach's Alpha
Digital Literacy	1. Utilization of digital technology 2. Evaluation of digital learning resources 3. Management of digital information 4. Digital content development 5. Digital-based communication 6. Digital ethics & security	23	20	0.820

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TPACK Competence	1. Integrated lesson design 2. Technology-based learning activities 3. Facilitation of Spatial Analysis 4. Evaluation of technology effectiveness 5. Modification of instructional plans	21	16	0.871
Teaching Performance	1. Lesson planning 2. Instructional implementation 3. Learning evaluation	14	14	0.794

Source: Research Data Analysis

Validity was assessed using Pearson Product Moment correlation at the 5% significance level, while reliability was evaluated using Cronbach's Alpha. The digital literacy instrument achieved a reliability coefficient of $\alpha = 0.820$, indicating strong internal consistency. Both the TPACK and teaching performance instruments also met the established reliability threshold ($\alpha > 0.70$). The use of a Likert-scale self-report instrument in this study is consistent with the dominant practice in TPACK research. Gonscherowski & Rott (2025), in a systematic review of 215 TPACK assessment studies from 2017 to 2023, found that self-assessment instruments were by far the most frequently used method (73% of studies), largely because they are practical to administer at scale. The authors nonetheless acknowledge a well-documented limitation: such instruments assess teachers' self-perceptions rather than directly measuring competence, and are susceptible to social desirability bias. This limitation is equally acknowledged in the present study.

Data Analysis

Prior to hypothesis testing, a series of classical assumption tests required for multiple linear regression were conducted. These included the Kolmogorov-Smirnov test for normality, the Test for Linearity for linear relationships, the Variance Inflation Factor (VIF) for multicollinearity, and the Glejser test for heteroscedasticity. All assumptions were satisfied, permitting the regression analysis to proceed.

Hypothesis testing was conducted in two stages. First, Pearson Product Moment correlation analysis was used to examine the bivariate relationship between each independent

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variable and teaching performance. Second, multiple linear regression was used to examine the unique contribution of each predictor after controlling for the other predictor. All analyses were performed using SPSS. Correlation strength was interpreted according to Sugiyono's (2019) criteria, whereby coefficients of 0.40–0.599 indicate a moderate relationship and 0.60–0.799 indicate a strong relationship.

DISCUSSION

Respondent Profile and Descriptive Statistics

The study involved 70 geography teachers from SMA/MA schools distributed across six regencies and municipalities in Gorontalo Province. The largest proportion of respondents came from Gorontalo Regency (21.43%), followed by Boalemo and Bone Bolango Regencies (18.57% each), and Gorontalo City (17.14%). In terms of teaching experience, the majority were seasoned educators: 48.57% had 5–10 years of experience and 37.14% had more than 10 years, leaving only 14.29% with fewer than five years in service. This composition is noteworthy, as extensive teaching experience may simultaneously foster resistance to technology-driven change and serve as a pedagogical asset that strengthens technology integration when paired with adequate digital competence.

The descriptive profiles of the three study variables are presented in Table 2. Digital literacy recorded a mean of 76.37 out of a maximum score of 100, indicating a reasonably high overall digital capacity. TPACK competence yielded a mean of 64.16 out of a maximum of 80, a satisfactory figure, though the standard deviation (SD = 8.104) reflects considerable variation among teachers. Teaching performance had a mean of 56.61 out of a maximum of 70, with the smallest data spread (SD = 7.008), suggesting that instructional performance was relatively uniform across respondents, despite a fairly wide observed score range (42–70).

Table 2. Descriptive Statistics of Study Variables

Variable	N	Min	Max	Mean	SD
Digital Literacy (X_1)	70	50	93	76.37	9.359
TPACK Competence (X_2)	70	46	78	64.16	8.104
Teaching Performance (Y)	70	42	70	56.61	7.008

Source: Research Data Analysis

A closer comparison of the three mean values reveals an important nuance. When converted to a percentage of each variable's maximum score, digital literacy stands at 76.4% while

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TPACK reaches 80.2%, a relatively modest gap. However, a different picture emerges when examining score distributions: TPACK scores span a narrower absolute range (46–78), yet the inter-teacher variance is proportionally higher relative to its mean. This pattern suggests that TPACK capacity among geography teachers in Gorontalo is unevenly distributed, with some teachers demonstrating strong competence while others lag considerably, particularly in components requiring subject-specific technology integration such as GIS and spatial data analysis.

The Relationship Between Digital Literacy and Teaching Performance

Pearson Product Moment correlation analysis yielded a coefficient of $r = 0.484$ ($p < 0.001$), placing the relationship between digital literacy and teaching performance in the moderate category while remaining statistically significant (Table 3). The positive direction of the relationship confirms that teachers with stronger digital capacity tend to demonstrate higher instructional quality.

Table 3. Pearson Product Moment Correlation Results

Variable Relationship	r	Sig.	Category
Digital Literacy (X_1) → Teaching Performance (Y)	0.484	< 0.001	Moderate
TPACK Competence (X_2) → Teaching Performance (Y)	0.532	< 0.001	Moderate

Source: Research Data Analysis

The moderate correlation, however, warrants careful interpretation. Rather than reflecting a limitation, it mirrors the inherent complexity of the relationship between digital competence and instructional quality. Digital literacy is a generalist construct: the ability to access, evaluate, and communicate digital information does not automatically determine how effectively a teacher designs and delivers instruction. A teacher may be highly proficient in using social media, video streaming platforms, or search engines, yet still lack the capacity to translate those skills into pedagogically sound, geography-specific learning designs.

This finding aligns with Judijanto (2024), who similarly reported a significant yet moderate correlation between digital literacy and instructional quality among teachers across subject areas. Temirkhanova et al. (2024) further corroborate this, finding that teachers with higher technological knowledge and stronger ability to integrate digital tools into their pedagogy produced greater improvements in student outcomes, reinforcing that the impact of digital literacy on teaching quality is contingent on how effectively it is applied in instructional practice. Sugiarto & Dewantara (2021) further clarified the underlying mechanism: social studies teachers

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with higher digital literacy are more adaptive in selecting instructional methods and media, but this adaptability is contingent on the depth of pedagogical understanding accompanying their digital skills. In the geography context, this distinction is particularly pronounced. Functionally meaningful digital literacy for a geography teacher is not merely the ability to search for information online, but the capacity to access and process geospatial data from platforms such as the Geospatial Information Agency (BIG), Google Earth Engine, or satellite imagery repositories, and to integrate that data into contextually relevant, phenomenon-based instructional materials.

The mean digital literacy score of 76.37 conceals a more nuanced story at the indicator level. The most prominent weakness lies not in basic internet access skills, but in digital content development, specifically the ability to independently create or adapt digital learning media suited to the goals and content characteristics of geography instruction. This pattern indicates that geography teachers in Gorontalo Province have progressed beyond the first tier of digital literacy (access and use) but have not yet fully reached the higher tier (content creation and adaptation), which has the most direct bearing on instructional quality.

The Relationship Between TPACK Competence and Teaching Performance

TPACK competence demonstrated a stronger correlation with teaching performance than digital literacy ($r = 0.532$; $p < 0.001$). The numerical difference between the two coefficients (0.048) may appear modest, yet it carries meaningful conceptual weight.

TPACK is not simply a higher-order form of digital literacy; the two constructs measure conceptually distinct capacities. Digital literacy assesses an individual's general command of the digital ecosystem, whereas TPACK measures teaching-specific knowledge, namely how a teacher simultaneously integrates technology, pedagogical strategies, and subject matter content in classroom practice. Mishra & Koehler (2006) emphasized that effective technology integration in learning depends not on technological mastery per se, but on the teacher's relational understanding of how technology, pedagogy, and content interact. A teacher with strong TPACK does not merely know what can be done with Google Earth; they know when it is most appropriate to use it, how to guide students in using it to develop spatial reasoning, and why it is more effective than alternative tools for a particular geography topic.

Because TPACK is more directly tied to the practical dimensions of teaching, including technology-integrated lesson planning, spatial data-based instructional activities, and technology-assisted assessment of students' geography content understanding, it is reasonable that its correlation with teaching performance is stronger. This is further supported by Panakaje et al.

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(2024), who found that technology integration significantly influences teacher performance through the mediation of teacher learning and pedagogical strategies, reinforcing that the relationship between technology competence and instructional quality is not direct but is shaped by how teachers apply that competence in practice. Pulungtana & Dwikurnaningsih (2020) found a comparable pattern among social studies teachers, reporting a positive relationship between TPACK implementation and teaching performance, particularly in lesson planning and instructional delivery. Listiqowati (2024) reinforced this argument by demonstrating that teachers with stronger TPACK produce more interactive, contextually grounded, and relevant learning experiences.

A particularly instructive comparison is provided by Nofrion et al. (2018), whose study of geography teachers in Solok Regency found TPACK at a moderate level with primary deficiencies in technology integration during instruction, a pattern strikingly similar to the conditions observed in Gorontalo Province. Jiménez Sierra et al. (2023), in a systematic review of TPACK development studies across multiple national contexts, found that the integration of technology with specific content knowledge remains the most persistent developmental challenge among teachers, across diverse national contexts. Their review further confirms that meaningful TPACK development requires situated, collaborative, and practice-based learning environments rather than isolated technology training. The fact that two studies conducted in different regions approximately eight years apart reveal nearly identical patterns suggests that this is not a localized issue but rather a structural challenge in the professional development of geography teachers at the national level. The persistent gap between functional technology use and pedagogically integrated technology application appears to be a chronic and systemically unaddressed problem.

From a practical standpoint, the TPACK components most urgently requiring reinforcement are Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK). TCK pertains to teachers' understanding of how specific technologies, such as GIS, multispectral imagery, or AI-based spatial data analysis platforms, can fundamentally transform how geography content is represented and understood. TPK addresses teachers' ability to select the most effective technology-enhanced instructional strategies, for instance, designing inquiry-based activities using geospatial data or simulating land-use changes through temporal satellite imagery analysis.

Simultaneous Relationships and Predictor Interaction Dynamics

The simultaneous regression test yielded $F = 14.687$ ($p < 0.001$) with a coefficient of

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determination $R^2 = 0.305$, indicating that digital literacy and TPACK together account for 30.5% of the variance in teachers' teaching performance (Tables 4 and 5).

Table 4. Multiple Linear Regression Model Summary

	R	R^2	*Adjusted R^2*	*Std. Error*
Model	0.552	0.305	0.284	5.930

Source: Research Data Analysis

Table 4. Regression Coefficients

Variable	B	Beta (β)	t	Sig.
Constant	23.407	-	3.752	< 0.001
Digital Literacy (X_1)	0.159	0.212	1.452	0.151
TPACK Competence (X_2)	0.329	0.380	2.605	0.011

Source: Research Data Analysis

The resulting regression equation is: $\hat{Y} = 23.407 + 0.159X_1 + 0.329X_2$. The R^2 value of 0.305 indicates that digital literacy and TPACK jointly explain 30.5% of the variance in teaching performance, a substantive proportion given that teaching performance is a multidimensional construct shaped by numerous factors beyond digital competence, including teachers' intrinsic motivation, school climate, principal leadership, technology infrastructure, and administrative workload. The 30.5% contribution from two digital competency variables alone, without controlling for other factors, indicates that digital literacy and TPACK have a meaningful statistical association with teachers' self-perceived instructional quality. This is consistent with Suyanto's (2019) contention that teacher competency development in the digital era is one of many systemic factors that collectively shape educational quality.

The most theoretically meaningful finding in this study, however, lies not in the R^2 value itself, but in the dynamics that emerge when both predictors are entered into the model simultaneously. When analyzed individually, both digital literacy and TPACK showed significant correlations with teaching performance. Yet in the multiple regression model, the partial contribution of digital literacy became non-significant ($\beta = 0.212$; $p = 0.151$), while TPACK remained significant ($\beta = 0.380$; $p = 0.011$). This phenomenon cannot be interpreted as evidence that digital literacy is unimportant; rather, it reflects the substantial conceptual overlap between the two predictors.

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The correlation between digital literacy and TPACK (r = 0.716) indicates a substantial intercorrelation between the two predictors. Although the VIF value remains within acceptable limits, this shared variance may explain why digital literacy loses statistical significance in the regression model. Conceptually, this pattern suggests that digital literacy and TPACK share substantial common variance, and that TPACK appears to capture much of the predictive space previously attributed to digital literacy when both are entered simultaneously. This aligns with Ng et al. (2023), whose conceptual framework affirms that digital literacy serves as a foundational prerequisite for teachers' TPACK development, and that once TPACK is established, it becomes a more direct and stronger predictor of instructional quality than digital literacy alone. Cui & Zhang (2022) argue that technological knowledge is the core of digital literacy and a foundational component of TPACK, and that without adequate technological knowledge, teachers cannot develop the integrated competence required to effectively combine pedagogy, content, and technology in instructional practice. Zeng et al. (2022), in a meta-analysis of 28 studies involving 7,777 subjects, confirmed a moderate positive correlation between teachers' technology integration self-efficacy and TPACK ($r = 0.607$, $p < 0.001$), establishing that teachers' belief in their own digital capability serves as a foundational prerequisite for TPACK development.

This relationship makes theoretical sense. TPACK requires Technological Knowledge (TK) as one of its three foundational pillars, and TK is essentially the core of digital literacy. Teachers with weak digital literacy almost inevitably possess limited TK, which in turn constrains their TPACK development. Conversely, teachers with strong digital literacy possess robust TK as the foundational capital for developing more integrated TPACK. In other words, digital literacy may function as an enabling condition for TPACK development. Without adequate digital literacy, TPACK is unlikely to flourish. However, whether digital literacy's influence on teaching performance is formally mediated by TPACK remains an empirical question that future research employing formal mediation analysis, such as bootstrapped indirect effect estimation, should address.

This understanding carries important implications. Professional development programs that focus exclusively on enhancing digital literacy without simultaneously strengthening pedagogical and content integration, such as generic digital application training, are unlikely to produce meaningful improvements in geography teachers' instructional performance. By contrast, programs specifically designed to build contextualized TPACK, such as workshops on GIS integration in geography instruction, hands-on training in satellite imagery analysis for land-use change studies, or the use of AI-based platforms for designing spatially grounded assessments,

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are likely to have a far more direct impact on instructional quality.

These findings also provide an empirical basis for more targeted policy recommendations. The Gorontalo Provincial Education Office and the Geography Teachers' Working Group (MGMP Geografi) are advised against treating digital literacy enhancement and TPACK strengthening as separate programmatic agendas. Both must be embedded within a single, coherent, and sustained professional development ecosystem. Classroom-based coaching that affords teachers direct feedback on how they integrate technology in live instructional settings has been shown to be more effective than single-session informational training in which teachers are primarily passive recipients of content (Pasaribu et al., 2025). This aligns with Amemasor et al. (2025), whose systematic review of 23 studies confirms that one-time workshops are insufficient for sustained digital literacy development, and that meaningful integration of technology requires ongoing, context-specific professional development programs.

One methodological limitation warrants acknowledgment. All data were collected through self-report instruments, meaning that the digital literacy, TPACK, and teaching performance scores reflect teachers' self-perceptions rather than direct observations of classroom practice. The gap between perceived and actual competence is a well-documented phenomenon in teacher competency research (Nofrion et al., 2018), and is likely present in this sample as well. This does not diminish the statistical validity of the findings, but it is a reminder that the values reported here are proxies for reality, not direct representations of it.

CONCLUSION

This study demonstrates that both digital literacy and TPACK competence have significant positive relationships with the teaching performance of geography teachers at SMA/MA in Gorontalo Province, with TPACK showing a stronger association ($r = 0.532$) than digital literacy ($r = 0.484$). Together, the two variables account for 30.5% of the variance in teaching performance ($F = 14.687$; $p < 0.001$). The most substantive finding is that in the multiple regression model, the unique contribution of digital literacy becomes non-significant when TPACK is controlled, a pattern suggesting that digital literacy and TPACK share substantial common variance, and that the role of digital literacy as a potential prerequisite for TPACK, rather than an independent predictor of teaching performance, warrants further investigation through formal mediation analysis.

The practical implication is clear: enhancing digital literacy and strengthening TPACK cannot be treated as separate professional development objectives. Geography teacher

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development programs must be designed in an integrated, geography-specific manner and sustained through classroom-based coaching. Future research employing a mixed-methods approach that incorporates direct classroom observation will yield a richer and more accurate understanding of how teachers' digital competencies manifest in actual instructional practice.

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