Analysis of Digital Competence of Teachers of Leading Schools Based on TPACK: A Case Study at SD Negeri 3 Cakul

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Abstract. This study investigates the digital competence of Penggerak School teachers at SD Negeri 3 Cakul, Trenggalek Regency, through the Technological Pedagogical Content Knowledge (TPACK) framework, focusing on Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). Using a qualitative case study approach, data were gathered through in-depth interviews, classroom observations, and documentation analysis involving eight teachers. Results indicate that TK scores ranged from 84% to 92%, reflecting good to excellent command of digital devices and applications, despite unstable internet connectivity in this rural setting. PK competence was demonstrated through varied instructional strategies, technology-integrated class management, and holistic assessment approaches. CK competence showed comprehensive mastery of curriculum-aligned subject matter, contextualised with students' daily lives, and enriched through validated digital sources. Collectively, these three foundational domains underpin effective TPACK integration. The findings validate the TPACK framework in the Indonesian primary school context and suggest that digital competence development depends not only on infrastructure but also on collaborative learning culture and instructional leadership.

Keywords: TPACK, digital competence, Penggerak School, rural school, teacher knowledge

1 Introduction

The global acceleration of digital transformation has fundamentally reshaped the landscape of education, placing teachers at the center of a complex challenge: how to integrate rapidly evolving technology into meaningful learning experiences. In Indonesia, this imperative has been institutionalized through strategic government initiatives, most notably the Merdeka Belajar curriculum and the Sekolah Penggerak program, which positions schools as transformation agents for improving holistic student outcomes [1]. Within this policy context, teacher digital competence has emerged not merely as a technical requirement but as a prerequisite for pedagogical quality.

The Technological Pedagogical Content Knowledge (TPACK) framework, originally conceptualized by Mishra and Koehler [2] and further elaborated by Koehler and Mishra [3], provides the most comprehensive theoretical architecture for understanding how teachers integrate technology into subject-specific pedagogy. TPACK posits that effective technology integration is not reducible to device proficiency; it demands the simultaneous and dynamic intersection of three knowledge domains: Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK). Their overlapping intersections Technological Pedagogical Knowledge (TPK), Technological Content Knowledge (TCK), and their totality in TPACK constitute the theoretical core of this study.

Despite the growing body of TPACK research globally, critical gaps remain in the Indonesian context, particularly concerning rural and mountainous elementary schools where infrastructure constraints coexist with national digitalization mandates. Most existing studies on Sekolah Penggerak have focused on managerial and curricular dimensions [1], while digitally grounded analyses of teacher competence remain sparse. Gencel [4] demonstrated that TPACK must account for contextual and self-efficacy factors, yet studies situating TPACK within Indonesia's rural digital divide remain limited.

SD Negeri 3 Cakul, located at the border of Dongko and Panggul sub-districts in Trenggalek Regency, represents a particularly significant case. Classified as a Sekolah Penggerak, the school operates in a mountainous area with restricted internet connectivity (Local Area Network at 1 Mbps), limited devices (15 Chromebooks and five laptops for 83 students), and a teaching staff of eight whose digital backgrounds are heterogeneous. The tension between the school's progressive mandates under the Merdeka Belajar curriculum and its infrastructural

realities makes it an ideal site for a contextually rich TPACK analysis. Pratiwi and Dewi [5] have documented that teachers in remote schools frequently face barriers in adopting digital learning media; this study investigates how teachers at SD Negeri 3 Cakul navigate and transcend such barriers.

The overarching research question guiding this inquiry is: how do Sekolah Penggerak teachers at SD Negeri 3 Cakul demonstrate and develop digital competence across the three foundational TPACK domains of TK, PK, and CK? Answering this question yields both theoretical contributions to TPACK scholarship and practical implications for teacher professional development policy in rural Indonesia.

2 Methods

This study adopted a qualitative case study design, selected because it enables rich, contextualized investigation of a bounded social phenomenon in this instance, the TPACK-based digital competence of teachers within the unique organizational and geographic context of SD Negeri 3 Cakul. Case study methodology, as affirmed by its appropriateness for exploring phenomena in their natural setting, permits the researcher to capture the complexity, meaning, and process dimensions that quantitative designs cannot fully illuminate.

Eight teachers participated as research subjects (Table 1): six class teachers (Grades I–VI) and two subject specialist teachers (Physical Education and Islamic Studies). Six hold Civil Servant (ASN) status and are certified; two are non-certified volunteer teachers. This diversity in status, experience (3–18 years), and subject specialty enabled a multifaceted portrayal of TPACK expression.

Table 1. Profile of Research Participants

Code	Gender	Status	Role	Teaching Exp. (years)	Certification
AND	Female	ASN	Class VI Teacher	15	Certified
WUL	Female	ASN	Class V Teacher	12	Certified
SUP	Male	ASN	Class IV Teacher	18	Certified
MOH	Male	ASN	Class III Teacher	10	Certified
AMI	Female	Volunteer	Class II Teacher	4	Non-Certified
FIT	Female	Volunteer	Class I Teacher	3	Non-Certified
SYA	Male	ASN	Physical Education	14	Certified
FAD	Male	ASN	Islamic Studies	11	Certified

Data were collected through three triangulated techniques. First, in-depth semi-structured interviews were conducted with each teacher to elicit self-reported understanding, practices, and challenges across TK, PK, and CK. Second, direct classroom observations were performed using a five-point TPACK observation rubric, validated through expert judgment by academic supervisors. Each teacher was observed during at least two instructional sessions. Third, documentation analysis examined lesson plans (Modul Ajar), digital learning media, student worksheets (LKPD digital), quiz instruments, and training certificates.

Data analysis followed Miles and Huberman's interactive model: data collection, data reduction organized by TPACK components, data display through narrative and tabular presentation, and conclusion drawing through iterative verification. Trustworthiness was ensured through source triangulation (interview, observation, documentation), member-checking, and prolonged engagement at the research site from December 2025 to January 2026.

3 Results and Discussion
3.1 Technological Knowledge (TK) of Sekolah Penggerak Teachers
3.1.1 Device Proficiency and Digital Application Use

Results indicate that all eight teachers at SD Negeri 3 Cakul demonstrated consistent and functional Technological Knowledge, with observation scores ranging from 84% to 92% (Table 2). The highest-performing teachers were AND (92%) and FAD (91%), while AMI and FIT each scored 84% a differentiation reflecting contextual rather than fundamental competence gaps: lower-grade teachers appropriately selected simpler technologies suited to early childhood cognition, while upper-grade teachers deployed more complex, interactive platforms.

Table 2. Technological Knowledge (TK) Scores and Digital Practices

Teacher	Device Proficiency (%)	Digital App Score	Key Applications Used	Adaptive Strategy	Category
AND	92	90	Canva, Quizizz, GClassroom	Offline prep, blended	Excellent
WUL	87	88.7	PowerPoint, PDF, YouTube	Media backup	Good
SUP	90	85	Video, TV LED, PPT	Device check routine	Excellent
MOH	85	83	Multimedia, animation	Offline content	Good
AMI	84	82	YouTube, WhatsApp	WA group sharing	Good
FIT	84	83.7	Simple video, digital LKPD	Short-clip approach	Good
SYA	90	87.5	Kahoot, Wayground, IFP	Audio-visual integration	Excellent
FAD	91	90	PPT, ayat visual slides	Content-specific media	Excellent

All teachers demonstrated proficiency in operating core hardware: laptops, LCD projectors, Interactive Flat Panels (IFP), TV LEDs, and sound systems. Beyond hardware operation, their TK extended meaningfully into the domain of digital application use. AND, for instance, articulated a multi-layered digital toolkit: "In daily learning activities, the digital technologies I use include: laptop, LCD projector, slide presentations using PowerPoint in Canva, and also the IFP" (W/SF1/AND/06-I-2026). Teacher SYA's use of Kahoot and Wayground for gamified assessment exemplifies an advanced dimension of TK wherein digital tools are selected deliberately for pedagogical activation, not mere content delivery.

These findings align with Judijanto's [6] argument that teacher digital literacy plays a decisive role in determining learning quality, since the capacity to leverage technology is demonstrably linked to improved student critical thinking and engagement. Similarly, Nurohman et al. [7] observed that teachers who proactively integrate digital applications including AI-assisted platforms and interactive quizzes generate measurably richer student learning experiences. The TK profiles revealed here reflect precisely this proactive disposition.

3.1.2 Adaptive Strategies under Infrastructure Constraints

A defining characteristic of TK at SD Negeri 3 Cakul is the teachers' adaptive ingenuity in response to infrastructure limitations. The school's internet connectivity a single Local Area Network at 1 Mbps, unreliable and subject to frequent disruption represents a structural constraint that would ordinarily be expected to suppress digital teaching practices. Yet teachers consistently developed workaround strategies that preserved instructional quality. AND described downloading materials in advance and preparing offline backups before every lesson; WUL described caching PDF and video content locally; SYA integrated audio via sound systems as a robust alternative when internet-dependent platforms were unavailable.

This pattern directly challenges the infrastructural determinism critiqued by Wibowo and Setiawan [8], who documented urban-rural digital divides as significant barriers to digital competence development. The present findings suggest that the relationship is more nuanced: while infrastructure constrains, it does not preclude competence. Cultural and motivational factors particularly the Kelompok Kerja Guru (KKG) collaborative network and peer learning culture emerged as more powerful enablers of TK development than hardware availability. Sudirman and Latif [9] similarly noted that effective elementary school teachers find ways to blend simple yet purposive technology with pedagogical intent, and SD Negeri 3 Cakul's teachers exemplify this principle.

Crucially, teachers demonstrated ongoing, self-directed learning engagement. AND, for example, joined online educator communities on WhatsApp groups and social media to monitor emerging educational technologies. This behavior corresponds with the 'reflection and self-development' dimension of UNESCO's ICT Competency Framework for Teachers, which calls upon educators to continuously review and upgrade their technological practices. Elmi et al. [10] have argued that the professional identity of twenty-first-century teachers is increasingly constituted through digital reflexivity an identity characteristic clearly present in these teachers' self-descriptions.

3.2 Pedagogical Knowledge (PK) of Sekolah Penggerak Teachers
3.2.1 Instructional Strategy Repertoire

Teachers at SD Negeri 3 Cakul demonstrated Pedagogical Knowledge characterized by deliberate methodological diversity. None relied on a single instructional method; instead, each orchestrated a contextually responsive blend of approaches including interactive lecturing, group discussion, question-and-answer, demonstration, project-based learning, and play-based activities. Table 3 presents the pedagogical profiles observed across teachers.

Table 3. Pedagogical Knowledge (PK) Profiles of Participating Teachers

Teacher	Teaching Strategies Applied	Technology Integration Role	Classroom Management	Assessment Approach
AND	Discussion, Q&A, project-based	Concept clarifier, visual aid	Pre-use instruction	Digital quiz (formative)
WUL	Demonstration, group work, project	Engagement booster	Rule-setting protocol	LKPD digital + observation
SUP	Visual explanation, storytelling	Abstract concept mediator	Guided attention	Interactive Q&A
MOH	Q&A, seat arrangement, mixed	Attention sustainer	Seating + Q&A combo	Oral + digital quiz
AMI	Direct instruction + WA sharing	Extension outside classroom	Informal group rules	Observation + WA task
FIT	Simple video-based, play	Motivational visual	Short-duration media	Observation-based
SYA	Movement, music, active learning	Audio-visual coordinator	Physical + digital blend	Performance + digital
FAD	Recitation + visual narrative	Contextual embedding	Content-focused	Quiz + recitation

AND articulated the logic of this responsiveness clearly: "I usually adjust the method to the material; if the material requires gradual understanding, I use discussion and examples that are close to the students" (W/SF2/AND/06-I-2026). WUL similarly explained her preference for collaborative modalities: "Children today are more active when invited to practice directly, so I more often use group methods and simple project tasks" (W/SF2/WUL/08-XII-2025). These statements reflect the metacognitive awareness of PK that Puspitasari [11] identifies as essential: the capacity to make purposeful, context-sensitive pedagogical decisions rather than defaulting to habitual practice.

The pedagogical repertoire observed is consistent with Yulaikhah et al.'s [12] assertion that TPACK constitutes the foundational basis for adaptive digital competence standards in twenty-first-century education. The teachers' ability to fluidly move between instructional modes based on student response signals observed in real time illustrates what Koehler and Mishra [13] describe as the dynamic and context-dependent nature of pedagogical practice as one element of TPACK.

3.2.2 Technology as Pedagogical Mediator

A critical finding concerns how technology is positioned within these teachers' PK. Rather than deploying technology as a substitute for explanation or as a passive display medium, teachers consistently used it as an active pedagogical mediator. SUP explained: "Technology helps me explain material that is difficult for children to imagine, especially when there are images or animations" (W/SF2/SUP/02-XII-2025). AND echoed this when reflecting on outcomes: "When using videos or images from the internet, students understand more quickly compared to verbal-only explanation" (W/SF2/AND/06-I-2026).

This positioning of technology as conceptual scaffolding not mere decorative enrichment is precisely what Judijanto [6] identifies as a marker of high-order digital literacy. When technology mediates abstract-to-concrete concept translation, it functions as a genuine cognitive tool, not a motivational add-on. Nugraha [14] reinforces this by demonstrating that without appropriate teacher intervention and purposive technology use, digitalization produces minimal impact on student digital literacy outcomes. The teachers at SD Negeri 3 Cakul are clearly engaged in the kind of purposive intervention Nugraha describes.

3.2.3 Classroom Management in Technology-Enhanced Environments

Teachers demonstrated sophisticated awareness of the distraction potential inherent in technology-enhanced classrooms. Both WUL and MOH described structured pre-use protocols: "If I explain the rules first before starting, the children can be more orderly even when using the LCD" (W/SF2/WUL/08-XII-2025); and "Lower-grade students are easily distracted, so technology use must be interspersed with direct communication" (W/SF2/MOH/13-I-2026). This dual awareness of technology's affordances and its risks reflects the pedagogical maturity emphasized by Sudirman and Latif [9], who note that elementary-level teachers must integrate technology with particular sensitivity to students' developmental characteristics. Teachers who recognized that young learners require shorter technology exposure windows and more frequent direct interaction demonstrated an evidence-based understanding of cognitive load and attentional capacity in early childhood.

3.3 Content Knowledge (CK) of Sekolah Penggerak Teachers
3.3.1 Curriculum-Aligned Subject Mastery

Content Knowledge assessments revealed a consistently strong profile across all teachers, with observation scores ranging from 4 (Good) to 5 (Excellent) on a five-point scale (Table 4). Critically, CK at SD Negeri 3 Cakul was not merely declarative it encompassed relational understanding, contextual application, and the ability to sequence content logically for diverse learners. AND demonstrated the deepest CK profile, scoring 5 across observed sessions: "I understand the basic concepts, learning objectives, and the interconnections between materials so that I can explain clearly and systematically to students. I link the material to daily life and student experiences, making it more understandable and meaningful" (W/SF3/AND/06-I-2026).

Table 4. Content Knowledge (CK) Scores and Characteristics

Teacher	Obs. Score (1-5)	CK Characteristic	Content Contextualization Strategy	Digital Source Validation	Category
AND	5	Deep conceptual linkage	Real-life examples, student-context bridge	Cross-curriculum check	Excellent
WUL	4	Systematic subject mastery	Peer discussion, updated references	Credibility verification	Good
SUP	4	Adequate content mastery	Simplified language, concrete examples	Curriculum alignment	Good
MOH	4	Solid foundational knowledge	Step-by-step presentation	Relevance check	Good
AMI	4	Adequate, ongoing development	Community context, parental link	Basic source check	Good
FIT	4	Age-appropriate content	Concrete, play-based framing	Simplicity priority	Good
SYA	5	Specialized PE content	Movement-integrated learning	Video source validation	Excellent
FAD	5	Deep Islamic studies mastery	Textual + visual narrative	Scholarly reference check	Excellent

WUL's profile similarly reflected a commitment to continuous content updating: "I continuously update and deepen my understanding of the material through reading references, attending training, and discussing with colleagues" (W/SF3/WUL/08-XII-2025). This commitment to ongoing CK renewal resonates with Haryanti and Susilo's [15] finding that effective TPACK training must be anchored in contextual content development, not abstract technological skill-building. Teachers who actively update their subject matter knowledge are better positioned to make informed decisions about which digital representations most accurately and engagingly convey particular concepts.

3.3.2 Contextualization and Digital Source Validation

A distinctive feature of CK at SD Negeri 3 Cakul is the deliberate contextualization of content to the local socioeconomic reality of students. Given that the majority of students come from farming and labor families with limited home learning resources, teachers employed strategies including simplified language registers, concrete familiar examples drawn from agricultural life, graduated concept presentation, and multi-format media variation

to maximize accessibility. This socially responsive CK is consistent with Nurazizah and Utomo's [16] argument that teachers' capacity for critical and logical thinking is foundational to the contextualized problem-solving that deep learning requires.

Teachers also exhibited a critical stance toward digital content sources. Rather than uncritically accepting online materials, they implemented systematic validation processes: cross-referencing with Merdeka curriculum standards, assessing source credibility, evaluating content recency and relevance, and adjusting complexity for grade-appropriate comprehension. This behavior corresponds to the 'Digital Resources' competence area in the European DigCompEdu framework [17], which posits that teachers must not only locate but critically evaluate and ethically adapt digital materials. Fakhruddin et al. [18] have identified critical digital source evaluation as a key indicator of mature teacher digital competence in the Indonesian context a capacity the teachers at SD Negeri 3 Cakul exhibit systematically.

3.4 Discussion: The Integrative Dynamics of TK, PK, and CK in TPACK

Viewed through the TPACK lens, the findings at SD Negeri 3 Cakul reveal an emergent instructional pattern that transcends the sum of individual knowledge domains. The intersection of TK, PK, and CK manifests as a coherent three-phase lesson structure consistently observed across classrooms: stimulus/engagement through video or visual presentation (TK + CK dimension); exploration through collaborative discussion and active tasks (PK + CK dimension); and evaluation through digital quizzes with rapid feedback (TK + PK dimension). This three-phase pattern constitutes the practical expression of TPACK as [2] envision it a dynamic synthesis of all knowledge domains in the service of effective student learning.

The variation in TPACK scores across grade levels (84–85% for lower grades versus 87–92% for upper grades) does not reflect a competence hierarchy but rather an appropriate differentiation of technological complexity calibrated to student developmental levels. Lower-grade teachers deliberately employed simpler, shorter technology interactions (2–5 minutes of video, basic visual slides) while upper-grade teachers engaged more complex, interactive, and self-directed digital activities. Gencel [4] has argued exactly this point: TPACK expression is inherently context-dependent, and evaluating it requires accounting for the specific characteristics of the learning environment and student population. Subject-specialist teachers SYA (PE, 90%) and FAD (Islamic Studies, 91%) further demonstrate TPACK's universality across disciplinary contexts, confirming Koehler and Mishra's [3] original claim that TPACK applies across all subjects and grade levels.

Perhaps the most theoretically significant finding of this study is the demonstrated irrelevance of infrastructural determinism to TPACK quality. Despite operating with severely constrained internet connectivity, limited devices, and no technical support staff, the teachers at SD Negeri 3 Cakul achieved TPACK profiles that compare favorably with studies conducted in better-resourced urban settings. The enabling factors were cultural and organizational: a functioning KKG that served as a professional learning community, instructional leadership from the school principal that actively promoted lesson planning collaboration and technology adoption, and a school culture that normalized peer mentoring and reflective practice. Abraham et al. [19] documented precisely this dynamic in their study of Sekolah Penggerak principals, finding that instructional leadership specifically participatory goal-setting, co-planning support, and conducive learning environment creation was the strongest predictor of teacher professional development quality.

These findings carry significant implications for teacher professional development policy. Setiadi et al. [20] advocate for scaffolded professional learning that begins with comprehensive competence assessment. The differentiated TPACK profiles identified in this study with AND and FAD demonstrating the highest integration complexity and AMI and FIT demonstrating strong foundational competence with growth potential provide exactly the kind of granular competence mapping that contextualized, scaffolded professional development requires. Subhan et al. [21] further demonstrated that structured monitoring and evaluation systems for professional development not only track program alignment but also reveal changes in teaching strategy, increased professional reflection, and collaborative culture formation outcomes visible in the KKG dynamics at SD Negeri 3 Cakul.

The broader policy implication consistent with Sumarsih et al. [1] on the Merdeka Belajar curriculum is that the Sekolah Penggerak program's aspiration to develop holistic student Pancasila learner profiles is achievable even in rural, resource-constrained contexts, provided that teacher digital competence development is treated as a cultural and leadership investment rather than solely a hardware procurement problem. Asagar [22] reminds us that digital competence is ultimately a holistic capability encompassing confidence, criticality, and collaborative responsibility dimensions that infrastructure alone cannot produce.

4 Conclusion

This case study of SD Negeri 3 Cakul has demonstrated that Sekolah Penggerak teachers in a rural, infrastructurally constrained environment can achieve substantive and coherent TPACK competence.

Technological Knowledge was evidenced by device proficiency scores of 84–92% and the purposive use of diverse digital applications, sustained by adaptive offline strategies and continuous self-directed learning. Pedagogical Knowledge was characterized by deliberate methodological diversity, technology deployed as a conceptual mediator rather than a delivery mechanism, and developmentally sensitive classroom management. Content Knowledge reached 4–5 out of 5 across all teachers, reflecting deep subject mastery, local contextualization, and critical digital source validation.

The integration of these three domains produced a three-phase instructional model: stimulus, exploration, evaluation that constitutes a practical and replicable expression of TPACK in the Indonesian elementary school context. Crucially, the quality of this integration was driven less by infrastructure availability than by collaborative learning culture through KKG, instructional leadership, and contextually grounded professional commitment. These findings validate TPACK as a robust analytical framework for rural Indonesian schools and suggest that future teacher professional development programs must prioritize cultural and leadership dimensions alongside and perhaps above technological infrastructure investment.

Acknowledgements

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