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Analysis of TPACK-Based Learning for Teachers of Madrasah Tsanawiyah in Banyumas Regency, Indonesia

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Abstract

Integrating technology, pedagogy, and content knowledge is critical for effective teaching in the 21st century, particularly in the aftermath of the COVID-19 pandemic, which has intensified the reliance on digital tools in education. This study examines the interrelationships among the six components of the Technological Pedagogical Content Knowledge (TPACK) framework as demonstrated by Madrasah Tsanawiyah teachers in Banyumas Regency, Indonesia. A quantitative research design was employed, with participants selected through proportional random sampling from the population of Madrasah Tsanawiyah teachers in the region. Data were collected using a questionnaire based on a 4-point Likert scale and analyzed through Structural Equation Modeling (SEM). The findings indicate that each component: Technological Knowledge (TK), Pedagogical Knowledge (PK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK): exerts a positive and statistically significant influence on overall TPACK. Specifically, significant positive relationships were observed between TK and TPACK, PK and TPACK, TCK and TPACK, PCK and TPACK, and TPK and TPACK. These results underscore the necessity of reinforcing all dimensions of the TPACK framework to improve teaching effectiveness in Madrasah Tsanawiyah, with the quantitative analysis affirming the strength and significance of these associations.

Keyword: TPACK Competency Analysis, Digital Era Teaching. Pedagogical Content Knowledge, Technology Integration and Madrasah Tsanawiyah Teachers.

Abstrak

Integrasi teknologi, pedagogi, dan pengetahuan konten sangat penting untuk pengajaran yang efektif di abad ke-21, terutama setelah pandemi *COVID-19, yang telah meningkatkan ketergantungan pada alat digital dalam pendidikan. Penelitian ini bertujuan untuk menguji keterkaitan di antara enam komponen dari kerangka kerja Technological Pedagogical Content Knowledge (TPACK) yang ditunjukkan oleh guru Madrasah Tsanawiyah di Kabupaten Banyumas, Indonesia. Penelitian ini menggunakan desain penelitian kuantitatif, dengan partisipan yang dipilih secara proporsional random sampling dari populasi guru Madrasah Tsanawiyah di wilayah tersebut. Data dikumpulkan dengan menggunakan kuesioner berdasarkan skala Likert 4 poin dan dianalisis melalui Structural Equation Modeling (SEM). Temuan menunjukkan bahwa setiap komponen-Pengetahuan Teknologi (TK), Pengetahuan Pedagogis (PK), Pengetahuan Konten Pedagogis (PCK), Pengetahuan Konten Teknologi (TCK), dan Pengetahuan Pedagogis Teknologi (TPK): memiliki pengaruh positif dan signifikan secara statistik terhadap TPACK secara keseluruhan. Secara khusus, hubungan positif yang signifikan diamati antara TK dan TPACK, PK dan TPACK, TCK dan TPACK, PCK dan TPACK, dan TPK dan TPACK. Hasil ini menggarisbawahi*

pentingnya memperkuat semua dimensi kerangka kerja TPACK untuk meningkatkan efektivitas pengajaran di Madrasah Tsanawiyah, dengan analisis kuantitatif yang menegaskan kekuatan dan signifikansi hubungan ini.
Kata Kunci: *Analisis Kompetensi TPACK, Pengajaran Era Digital. Pengetahuan Konten Pedagogis, Integrasi Teknologi, dan Guru Madrasah Tsanawiyah.*

INTRODUCTION

The COVID-19 pandemic profoundly reshaped global education systems, accelerating the adoption of digital technologies and revealing significant disparities in teachers' preparedness to integrate technology, pedagogy, and content knowledge effectively. In Indonesia, this challenge is particularly evident in Madrasah Tsanawiyah (Islamic junior high schools), where educators must navigate the complexities of aligning Islamic pedagogical traditions with the demands of contemporary educational technologies. Quantitative assessments indicate that only 18.75% of Madrasah Tsanawiyah teachers in Banyumas Regency demonstrate a high level of Technological Pedagogical Content Knowledge (TPACK) mastery, while 21.25% exhibit only moderate proficiency (Isnaeni et al., 2025; Nurhalisa et al., 2025; Sofwan et al., 2024). These findings highlight the urgent need to examine systemic barriers to technology integration within under-researched Islamic educational settings, where infrastructural constraints and culturally specific teaching practices pose additional challenges to TPACK development. The pandemic served as a catalyst, accelerating the global integration of educational technology (EdTech) by an estimated five years, as institutions and educators rapidly adopted digital learning platforms such as Zoom and Google Classroom tools that continue to hold pedagogical value in the post-pandemic landscape (Rahimi et al., 2024; Z. Zhang & Wasie, 2023). This shift has enabled multimodal learning environments that blend digital technologies with traditional instruction, offering greater flexibility, increasing student engagement, and promoting globally relevant learning experiences for both students and educators(Akram et al., 2021; Celik et al., 2023; Rahimi et al., 2024).

This study aims to address a critical gap in the existing literature by analysing the level of Technological Pedagogical Content Knowledge (TPACK) among Madrasah Tsanawiyah teachers in Banyumas Regency, and by identifying the factors that influence its development. More specifically, it investigates how the six core TPACK framework components Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK) contribute to teachers' overall TPACK mastery. Using a quantitative research design, the study employs structural equation modelling (SEM) to examine the structural relationships among these knowledge domains and assess the extent to which each component influences TPACK mastery. This approach provides a more nuanced understanding of TPACK, moving beyond treating it as a unified or monolithic construct (Blonder et al., 2022; Hanafi, 2023; Mishra & Koehler, 2006; Thyssen et al., 2023). SEM, a robust multivariate statistical technique widely applied in educational research, is particularly effective for analyzing complex causal relationships among latent variables. It provides empirical insights into how the various components of TPACK interact and influence outcomes such as technology integration in instructional practices (Madzamba & Matorevhu, 2024; Mohammad-Salehi & ..., 2021; Qiu et al., 2022; Schlebusch et al., 2024; Viloria et al., 2019).

Existing TPACK research has predominantly focused on pre-service teachers in general education or high-income settings, yielding robust theoretical frameworks but limited actionable insights for in-service educators in rural, developing regions (Koyuncuoglu, 2021; Z. Zhang & Wasie, 2023). While studies in Indonesian Madrasahs have begun addressing cultural and institutional barriers (Azizah & Mardiana, 2024; Hanafi, 2023; Musrifah & Shah, 2024), they often prioritize qualitative explorations, neglecting systematic analyses of how individual TPACK components interact to shape overall mastery. Furthermore, the applicability of the TPACK framework-validated primarily in Western contexts-to Islamic education systems remains underexamined, despite divergences in curricular priorities (e.g., emphasis on religious pedagogy) and resource constraints (Machmud et al., 2022; Setyo et al., 2023). This gap perpetuates a critical disconnect: without context-specific evidence, professional development programs risk misaligning with Madrasah teachers' needs, reinforcing reliance on basic digital tools (e.g., textbook photos) over interactive pedagogies (Sulistiani et al., 2024; Thyssen et al., 2023; Umbase, 2023).

This study employs a quantitative approach to examine TPACK mastery among Madrasah Tsanawiyah teachers in Banyumas Regency, Indonesia, addressing existing limitations in the field. Unlike previous research, which often conceptualises TPACK as a single, undifferentiated construct, this study uses Structural Equation Modelling (SEM) to analyse the structural relationships among its core components: Technological Knowledge (TK), Pedagogical Knowledge (PK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK) and Technological Pedagogical Knowledge (TPK). By testing hypotheses regarding the individual and collective contributions of these components to integrated TPACK, the study moves beyond descriptive analysis to identify strategic leverage points for targeted intervention. Recent SEM-based studies conducted in Qatar and Indonesia have highlighted TCK and TPK as critical mediators in the development of TPACK, whereas PCK and PK tend to exhibit weaker direct effects (Aksin, 2023a; Castillo et al., 2024; Dina et al., 2023; Mansour et al., 2024; Windianingsih et al., 2023). These findings suggest that the challenges faced by Madrasah teachers may not stem from isolated deficiencies in TK or CK, but rather from the fragmented integration of technology with pedagogical and content knowledge, particularly in STEM (Science, Technology, Engineering and Mathematics) contexts.

The study hypothesizes that while each TPACK component exerts a significant positive influence on overall mastery, their holistic integration-not isolated proficiency-is the primary driver of effective technology-enhanced teaching. This argument challenges assumptions that technological upskilling alone suffices, positing instead that systemic support for pedagogical and content integration is equally critical. By mapping these relationships, the paper aims to inform targeted professional development programs that bridge the gap between Madrasah teachers' current practices and Indonesia's digital education goals. Ultimately, this research contributes to equitable educational transformation by providing a model for TPACK development tailored to the socio-cultural and infrastructural realities of Islamic schools in developing regions.

This study highlights that most previous TPACK research has focused on pre-service teachers in general education settings or developed countries, and tends to ignore madrasah teachers in developing regions who face their own cultural and infrastructural challenges. The research asserts that an approach that only emphasises improving teachers' individual technology skills is not sufficient to improve the quality of technology-based learning. As such, the authors challenge the assumption that mastery of technology in isolation is sufficient, and highlight the need for holistic integration of technological, pedagogical and content knowledge in the madrasah context. This study shows that a holistic integration of technological, pedagogical and content knowledge (TPACK) is much more important than simply mastering technology in isolation. As such, this study triggers a new discussion on the need for a systemic approach to teacher professional development, not just partial technology training.

METHOD

This study employs a quantitative research design, adopting a sequential explanatory approach specifically. According to Creswell (2019), this design integrates both quantitative and qualitative methods, with quantitative data collected and analysed first, followed by qualitative data to help explain or elaborate on the quantitative findings (Creswell, 2019). The research subjects are Madrasah Tsanawiyah teachers from across Banyumas Regency, representing a diverse range of educational backgrounds and teaching experience. According to data from the Ministry of Religious Affairs of the Republic of Indonesia (EMIS), there are 57 Madrasah Tsanawiyah in the region, employing a total of 1,021 teachers. Participants were selected using proportional random sampling, ensuring representation based on key characteristics of the teacher population. This approach is consistent with prior research emphasising the importance of considering characteristics such as educational background and teaching experience when it comes to influencing the development of Technological Pedagogical Content Knowledge (TPACK). The sampling framework includes the following proportions: (1) approximately 70% of teachers hold a bachelor's degree in education (e.g. guidance and counselling, mathematics education, English language education, Arabic language education, science education, Indonesian language education or Islamic religious education) and have one to five years of teaching experience; (2) 10% of teachers have between five and 20 years of teaching experience; (3) 10% have more than 20 years of teaching experience; (4) 10% are school principals.

This study used a structured questionnaire to collect data, which served as the primary research instrument for gathering quantitative data. The questionnaire was administered electronically via Google Forms, enabling respondents to select their answers by clicking on the relevant number. A 5-point Likert scale was used to measure participants' levels of agreement or the frequency with which they engaged in certain behaviours, depending on the context of the statements. For items assessing agreement, the scale was defined as follows: 4 = Strongly Agree, 3 = Agree, 2 = Disagree and 1 = Strongly Disagree. For items assessing frequency, the scale was defined as follows: 4 = Always, 3 = Often, 2 = Sometimes, and 1 = Never. This approach to scaling enables a nuanced assessment of respondents' perceptions and behaviours relevant to the research objectives.

The TPACK (Technological Pedagogical Content Knowledge) instrument used in this study consists of 70 items distributed across the seven components of the framework: Fourteen items assess Technological Knowledge (TK), 14 assess Pedagogical Knowledge (PK), 14 assess Content Knowledge (CK), seven assess Pedagogical Content Knowledge (PCK), seven assess Technological Content Knowledge (TCK), seven assess Technological Pedagogical Knowledge (TPK) and seven assess the integrated TPACK construct. The questionnaire was adapted from instruments developed by Aksin (2023b), Mishra & Koehler (2006), Mohammad Salehi.(2021) and Schmidt et al (2009). To ensure the quality of the instrument, construct validity was assessed using Aiken's V index (Aiken, 1985), while reliability was evaluated using Cronbach's alpha. A threshold of $r \geq 0.70$ was used to indicate acceptable internal consistency (Aiken, 1985), and the reliability index followed the same criteria ($r \geq 0.70$) (Aiken, 1985; Thyssen et al., 2023).

The TPACK score was calculated to evaluate the interrelationships among the components possessed by Madrasah Tsanawiyah teachers. Hypothesis testing was conducted using structural equation modelling (SEM), a comprehensive statistical technique used to assess the structural and measurement models of complex constructs simultaneously (Walther et al., 2024). For this study, SEM was implemented using LISREL (Linear Structural Relations) software. Prior to hypothesis testing, prerequisite analyses were carried out, including a multivariate normality test for endogenous variables and a multicollinearity test for exogenous variables, to ensure the validity of the SEM assumptions. The model's Goodness of Fit (GoF) was assessed using multiple fit indices. According to Pedhazur (Tatsuoka, 1983) a model demonstrates acceptable overall fit if the GFI exceeds 0.90 and the AGFI exceeds 0.80. Furthermore, the model is considered to fit perfectly if the Chi-Square, Root Mean Square Residual (RMR) and Standardized RMR (SRMR) approach zero.

RESULT AND DISCUSSION

Measurement of TPACK Components

Table 1. Research Variables

No	Variable Name	Variable Code
1.	Technological Knowledge (TK)	X_1
2.	Pedagogical Knowledge (PK)	X_2
3.	Technological Content Knowledge (TCK)	X_3
4.	Pedagogical Content Knowledge (PCK)	X_4
5.	Technological Pedagogical Knowledge (TPK)	X_5
6.	Technological Pedagogical And Content Knowledge (TPACK)	Y

Technological Knowledge (TK) refers to a teacher's ability to utilize a range of technologies, from basic hardware to advanced digital tools. In this study, TK was measured using 14 items that assessed skills such as operating search engines (e.g., Google), using laptops or personal computers, navigating features in Microsoft Office, creating instructional videos, and utilizing various educational software.

Pedagogical Knowledge (PK) involves the ability to manage classrooms effectively, design lesson plans, structure appropriate learning experiences, understand student characteristics, and conduct assessments. This dimension was measured through 14 items addressing differentiation in instruction, the application of constructivist learning theories, various teaching models, assessment strategies, and the implementation of remedial and enrichment activities.

Content Knowledge (CK) reflects the teacher's mastery of the subject matter to be delivered in the classroom. In this study, CK was assessed through 14 items evaluating teachers' understanding of subject content relevant to the Madrasah Tsanawiyah curriculum. Pedagogical Content Knowledge (PCK) represents the integration of pedagogical strategies with content knowledge, enabling teachers to tailor their instructional methods to the specific nature of the subject matter. PCK was measured using seven items designed to assess teachers' abilities to adapt teaching practices according to the characteristics of the content. Respondents answered using a 5-point Likert scale: Strongly Disagree (STS), Disagree (TS), Neutral (R), Agree (S), and Strongly Agree (SS).

Technological Content Knowledge (TCK) refers to a teacher's ability to integrate technology effectively in delivering subject matter content, thereby enhancing students' conceptual understanding in a structured and systematic manner. In this study, TCK was measured using seven statements that assessed respondents' capabilities in utilizing information and communication technologies (ICT) to develop, support, and reinforce instructional materials aligned with curricular objectives. The results reflect respondents' proficiency in employing technology to strengthen content delivery.

Technological Pedagogical Knowledge (TPK) involves understanding how to use technological tools to support various aspects of pedagogy, including instructional strategies, classroom management, and assessment practices. In this study, TPK was assessed through seven items designed to evaluate respondents' ability to integrate ICT into the design and implementation of learning approaches, models, methods, media, and evaluation strategies. The items also examined teachers' ability to adapt technology use to accommodate the diverse characteristics and needs of their students.

Technological Pedagogical Content Knowledge (TPACK) refers to a teacher's ability to integrate technology effectively into instructional content while applying appropriate pedagogical strategies. In this study, TPACK was measured using seven statements that assessed the ability to: (1) align instructional content, pedagogical approaches, and information and communication technology (ICT) with students' characteristics; (2) tailor learning materials, models, and ICT tools to meet diverse student needs; (3) design instructional content and methods using ICT appropriately; (4) integrate real-life examples related to the content through ICT; (5) reinforce key concepts using ICT-based learning media; and (6) guide students in drawing conclusions using ICT resources.

The findings reveal that 3% of respondents did not complete the questionnaire and were categorized as missing data. A total of 80% of teachers reported having TPACK proficiency, with 7% indicating a high level of mastery. However, 13% of respondents expressed uncertainty, suggesting that a significant portion of teachers are still developing their TPACK competencies. The item with the highest mean score was item number 5, which assessed the ability to reinforce concepts using ICT-based media. In contrast, the lowest-scoring item was number 1, related to adjusting content, pedagogical approaches, and ICT to match students' characteristics. These results underscore the importance of strengthening teachers' adaptive capacity in aligning instructional strategies and technologies with learner needs especially in the context of the Industrial Revolution 4.0, where digital literacy and instructional innovation are critical. Strengthening TPACK competence is essential for promoting effective, engaging, and student-centered learning experiences that enhance motivation and academic outcomes..

Structural Relationship Analysis

After collecting the data and specifying the model, a structural relationship analysis was conducted using structural equation modelling (SEM). The SEM analysis results are presented in the screenshot below.

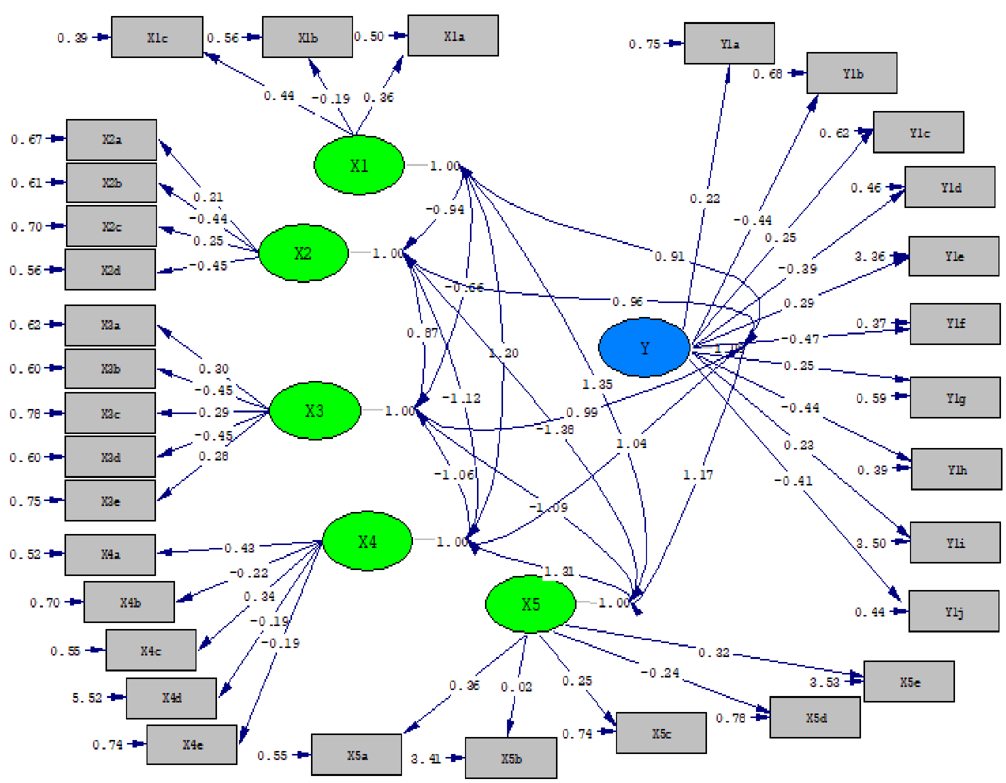

Figure 1. Output Standardized Solution

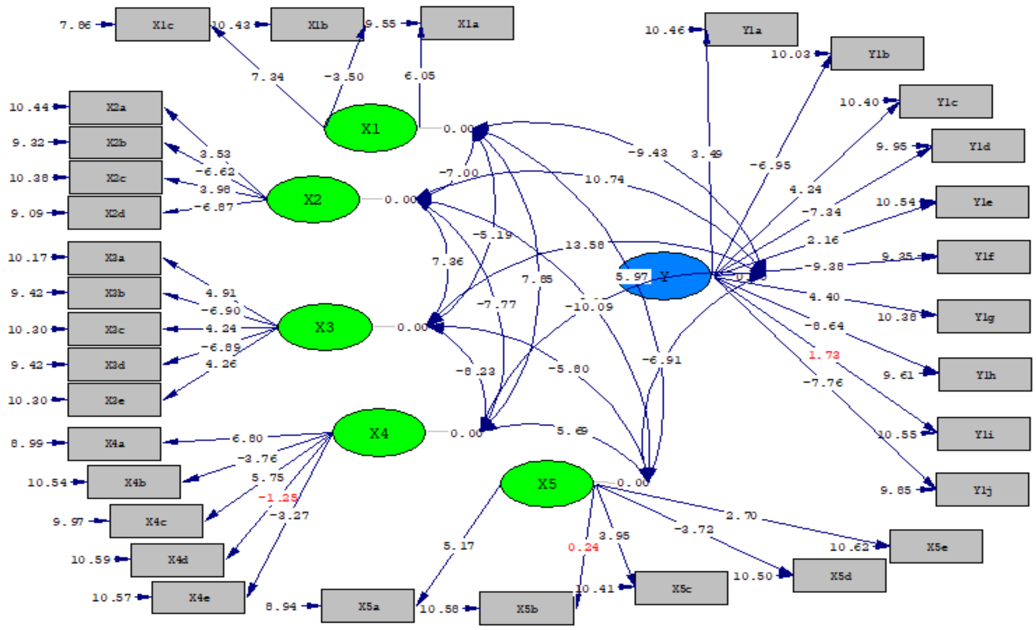

Figure 2. Output T-Value

Validity Test

The validity of each questionnaire item was assessed using Confirmatory Factor Analysis (CFA), supported by LISREL software. The results of the CFA provide evidence regarding the construct validity of the items in the instrument, as detailed below.

Table 1. Validity Test

No	Latent Variable	Indicator	Standardized loading	t-value	Conclusion
1.	X1	X1a	0.86	6.05	Valid
		X1b	0.19	3.50	Valid
		X1c	0.44	7.34	Valid
2.	X2	X2a	0.21	3.52	Valid
		X2b	-0.44	-6.62	Invalid
		X2c	0.25	3.98	Valid
		X2d	0.45	0.87	Valid
3.	X3	X3a	0.30	4.91	Valid
		X3b	-0.45	-6.90	Invalid
		X3c	0.29	4.24	Valid
		X3d	-0.45	-6.89	Invalid

		X3e	0.20	4.26	Valid
4.	X4	X4a	0.42	6.80	Valid
		X4b	-0.22	-3.76	Valid
		X4c	0.34	5.75	Valid
		X4d	-0.19	-1.25	Invalid
		X4e	-0.19	-3.27	Invalid
5.	X5	X5a	0.36	5.17	Valid
		X5b	0.02	0.24	Valid
		X5c	0.25	3.95	Valid
		X5d	-0.24	-3.72	Invalid
		X5e	0.32	2.70	Valid
6.	Y	Y1a	0.22	3.49	Valid
		Y1b	-0.44	-6.95	Invalid
		Y1c	0.25	4.24	Valid
		Y1d	-0.39	-7.34	Invalid
		Y1e	0.29	2.16	Valid
		Y1f	0.47	9.38	Valid
		Y1g	0.25	4.40	Valid
		Y1h	-0.44	-8.64	Invalid
		Y1i	0.22	1.72	Valid
		Y1j	-0.41	-7.76	Invalid

As shown in Table 1, indicators with positive factor loadings are considered valid, while those with negative values are deemed invalid. As the Construct Reliability (CR) value exceeds 0.70, it can be concluded that the instrument is highly reliable.

Reliability Test Results

Proposed the following formula for calculating construct reliability (CR):

$$\text{Construct Reliability (CR)} = \frac{\left(\sum_{I}^{P} \lambda ij\right)^2}{\left(\sum_{I}^{P} \lambda ij\right)^2 + \sum_{I}^{P} V(\delta i)} \quad \text{(Werts et al., 1974)}$$

CR calculation for indicator X_2.

Table 2. SDL Indicator Output X_2

Indicator	Std. Solution	Errors
X2a	0.30	0,60
X2c	0.29	0,70
X3d	0.20	0,56
Jumlah	0.79	1,93

$$CR = \frac{(1{,}93)^2}{(1{,}93)^2 + 0{,}79} = \frac{3{,}72}{(3{,}72) + 0{,}99} = \frac{3{,}72}{4{,}51} = 0{,}82$$

Table 3. CR Calculation Results for All Indicators

Latent Variable	CR Value	Conclusion
X_1	0.71	Reliable
X_2	0.82	Reliable
X_3	0.76	Reliable
X_4	0.77	Reliable
X_5	0.80	Reliable

Since the Construct Reliability (CR) value exceeds 0.70, it can be concluded that the instrument demonstrates a high level of reliability.

Model Fit Assessment

Prior to hypothesis testing, prerequisite analyses were conducted, including a multivariate normality test for endogenous variables and a multicollinearity test for exogenous variables. Subsequently, a Goodness-of-Fit (GOF) test was performed. The results of the GOF analysis are presented below:

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Goodness of Fit Statistics

Degrees of Freedom = 449
Minimum Fit Function Chi-Square = 958.27 (P = 0.0)
Normal Theory Weighted Least Squares Chi-Square = 1523.76 (P = 0.0)
Estimated Non-centrality Parameter (NCP) = 1074.76
90 Percent Confidence Interval for NCP = (959.93 ; 1197.16)

Minimum Fit Function Value = 4.28
Population Discrepancy Function Value (F0) = 4.80
90 Percent Confidence Interval for F0 = (4.29 ; 5.34)
Root Mean Square Error of Approximation (RMSEA) = 0.10
90 Percent Confidence Interval for RMSEA = (0.098 ; 0.11)
P-Value for Test of Close Fit (RMSEA < 0.05) = 0.00

Expected Cross-Validation Index (ECVI) = 7.51
90 Percent Confidence Interval for ECVI = (7.00 ; 8.05)
ECVI for Saturated Model = 4.71
ECVI for Independence Model = 16.83

Chi-Square for Independence Model with 496 Degrees of Freedom = 3705.65
Independence AIC = 3769.65
Model AIC = 1681.76
Saturated AIC = 1056.00
Independence CAIC = 3910.97
Model CAIC = 2030.64
Saturated CAIC = 3387.70
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Normed Fit Index (NFI) = 0.74
Non-Normed Fit Index (NNFI) = 0.82
Parsimony Normed Fit Index (PNFI) = 0.67
Comparative Fit Index (CFI) = 0.84
Incremental Fit Index (IFI) = 0.84
Relative Fit Index (RFI) = 0.71

Critical N (CN) = 122.94


Root Mean Square Residual (RMR) = 0.096
Standardized RMR = 0.10
Goodness of Fit Index (GFI) = 0.70
Adjusted Goodness of Fit Index (AGFI) = 0.65
Parsimony Goodness of Fit Index (PGFI) = 0.60
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Figure 4. Goodness of fit test result output

The summary of the model fit analysis results is presented in Table 4 below:

Table 4. Goodness-of-Fit Test Results

Fit Index	**Cut off Criteria**	**Estimated Result**	**Fit Level**
Absolute Match Index			
χ^2	p-value	p = 0.0	Good
Relative χ^2	χ^2 < 2 df	958.27 < 2 (449)	Good
RMSEA	> 0.07	0.10	Good
GFI	> 0.95	0.70	Not Good
AGFI	> 0.95	0.65	Not Good
SRMR	> 0.08	0.10	Good
Incremental Match Index			
NFI	>0.95	0.74	Not Good
NNFI	>0.95	0.82	Good enough
CFI	>0.95	0.84	Good enough
Parismoni Match Index			
AIC	Smaller or Closer to Saturated AIC	Model AIC = 1681,76 Saturated AIC = 1056	Not Good
CAIC	Smaller or Closer to Saturated CAIC	Model CAIC = 2030,64 Saturated CAIC = 3387.70	Good

Of the various measures *of goodness of fit* used, the index that indicates fit is more than that which indicates not fit so that the model can be inferred from the fit path model.

Hypothesis Testing

Hypothesis 1: The influences of pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK) and technological content knowledge (TCK) on technological knowledge (TK).

This hypothesis examines the relationships between these domains of knowledge and technological knowledge. The results of the structural equation modelling analysis are summarised in Table 5.

Table 5 Structural Relationships

No	Relationship	Loading Standardized	t-value	Conclusion
1.	X_2 to X_1	-0.94	9.42	No positive and significant effect
2.	X_3 to X_1	-0.66	10.74	No positive and significant effect
3.	X_4 to X_1	1.20	12.58	Positive and significant influence
4.	X_5 to X_1	1.25	10.09	Positive and significant influence

Conclusions based on data analysis:

1. Pedagogical knowledge (PK) does not have a positive, significant influence on technological knowledge (TK).
2. PCK (Pedagogical Content Knowledge) also does not have a positive and significant influence on TK (Technological Knowledge).
3. Technological pedagogical knowledge (TPK) has a positive and significant impact on technological knowledge (TK).
4. Technological content knowledge (TCK) has a positive and significant influence on technological knowledge (TK).

These findings suggest that, although pedagogical knowledge and pedagogical content knowledge do not significantly impact technological knowledge, both technological pedagogical knowledge and technological content knowledge are crucial for enhancing educators' technological competencies.

Hypothesis 2: The influence of technological knowledge (TK), pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK) and technological content knowledge (TCK) on pedagogical knowledge (PK).

This hypothesis explores the relationships between these forms of knowledge and PK. The findings from the structural equation modelling analysis are summarised in Table 6.

Table 6. Structural Relationships

No	Relationship	Loading Standardized	t-value	Conclusion
1.	X_1 to X_2	-0.94	9.2	No positive and significant impact
2.	X_3 to X_2	0.87	10.74	Positive and significant influence
3.	X_4 to X_2	-1.12	12.58	No positive and significant impact
4.	X_5 to X_2	-1.25	10.09	No positive and significant impact

Conclusions based on data analysis:

1. Technological knowledge (TK) does not have a positive, significant impact on pedagogical knowledge (PK).
2. PCK has a positive and significant influence on PK.
3. Technological pedagogical knowledge (TPK) does not significantly influence pedagogical knowledge (PK).
4. Technological Content Knowledge (TCK) has no positive, significant impact on PK.

These results suggest that, although PCK is a significant predictor of PK, the other factors (TK, TPK and TCK) do not substantially influence pedagogical expertise. Here is the revised version of your text with an enhanced academic tone and clarity:

Hypothesis 3: The influence of pedagogical knowledge (PK), technological knowledge (TK), technological pedagogical knowledge (TPK) and technological content knowledge (TCK) on pedagogical content knowledge (PCK).

This hypothesis investigates the relationships between the aforementioned knowledge components and PCK. The results of the structural equation modelling analysis are summarised in Table 7.

Table 7 Structural Relationships

No	Relationship	Loading Standardized	t-value	Conclusion
1.	X_1 to X_2	-0.66	9.42	No positive and significant impact
2.	X_3 to X_2	0.87	10.74	Positive and significant influence
3.	X_4 to X_2	-1.06	12.58	No positive and significant impact
4.	X_5 to X_2	-1.09	10.09	No positive and significant impact

Conclusions based on data analysis:

1. Pedagogical knowledge (PK) does not have a positive, significant influence on pedagogical content knowledge (PCK).
2. Technological knowledge (TK) has a positive and significant influence on PCK.
3. Technological pedagogical knowledge (TPK) does not have a positive and significant impact on pedagogical content knowledge (PCK).
4. Technological Content Knowledge (TCK) does not have a positive and significant influence on PCK.

These findings suggest that, although technological knowledge (TK) significantly influences pedagogical content knowledge (PCK), other factors such as pedagogical knowledge (PK), technological pedagogical knowledge (TPK) and technological content knowledge (TCK) do not play a significant role in enhancing PCK.

Hypothesis 4: examines the influence of PK, PCK, TK and TCK on TPK.

This hypothesis examines the extent to which pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological knowledge (TK) and technological content knowledge

(TCK) contribute to the development of technological pedagogical knowledge (TPK). The structural relationships are summarised in Table 8.

Table 8 Structural relationships

No	Relationship	Loading Standardized	t-value	Conclusion
1	X_1 to X_2	1.20	9.42	Positive and significant influence
2	X_3 to X_2	-1.12	10.74	No positive and significant impact
3	X_4 to X_2	-1.06	12.58	No positive and significant impact
4	X_5 to X_2	1.22	10.09	Positive and significant influence

Conclusion: Based on data analysis

1. Pedagogical knowledge (PK) positively and significantly influences technological pedagogical knowledge (TPK).
2. PCK does not significantly influence TPK.
3. Technological knowledge (TK) does not significantly influence TPK.
4. Technological content knowledge (TCK) has a positive and significant influence on TPK.

These findings suggest that TPK is shaped primarily through the integration of pedagogical expertise and the use of technology specific to the content, rather than through general content or technological knowledge in isolation.

Hypothesis 5: The influence of PK, PCK, TPK and TK on TCK.

This hypothesis examines the extent to which pedagogical knowledge (PK), pedagogical content knowledge (PCK), technological pedagogical knowledge (TPK) and technological knowledge (TK) contribute to the development of technological content knowledge (TCK). The structural relationships are summarised in Table 9.

Table 9. Structural Relationship

No	Relationship	Loading Standardized	t-value	Conclusion
1.	X_1 to X_2	1.25	9.42	No positive and significant impact
2.	X_3 to X_2	1.20	10.74	No positive and significant impact
3.	X_4 to X_2	-1.09	12.58	Positive and significant influence
4.	X_5 to X_2	1.22	10.09	Positive and significant influence

Conclusion: Based on data analysis

1. Pedagogical knowledge (PK) positively and significantly influences technological content knowledge (TCK).
2. PCK also has a positive and significant influence on TCK.
3. TPK does not have a positive or significant influence on TCK.
4. Technological knowledge (TK) has a positive and significant influence on TCK.

These results suggest that TCK is best developed through foundational pedagogical understanding, subject-matter integration and direct technological competence. However, the lack of significant influence from TPK suggests that pedagogical strategies involving technology do not directly enhance content-specific technological integration unless supported by core pedagogical and technological knowledge.

Hypothesis 6 investigates the influence of TK, PK, PCK, TPK and TCK on Technological Pedagogical and Content Knowledge (TPACK).

This hypothesis investigates the extent to which TK, PK, PCK, TPK and TCK contribute to TPACK. The structural relationships between these variables are presented in Table 10.

Table 10. Structural relationships

No	Relationship	Loading Standardized	t-value	Conclusion
1.	X_1 to Y	0.91	9.42	Positive and significant influence
2.	X_2 to Y	0.96	10.74	Positive and significant influence
3.	X_3 to Y	0.99	12.58	Positive and significant influence
4.	X_4 to Y	1.04	10.09	Positive and significant influence
5.	X_5 to Y	1.17	6.91	Positive and significant influence

Conclusion: Based on data analysis

The results of the structural equation modelling suggest that all five independent variables have a significant influence on the development of TPACK. Specifically:

1. Technological knowledge (TK) positively influences TPACK.
2. Pedagogical Knowledge (PK) significantly contributes to the formation of TPACK.
3. PCK (Pedagogical Content Knowledge) also has a strong positive effect on TPACK.
4. Technological pedagogical knowledge (TPK) significantly supports the integration of technology into pedagogical practices and content understanding.
5. Technological Content Knowledge (TCK) has a positive and significant influence on TPACK, reflecting the importance of aligning the use of technology with the delivery of content.

These findings suggest that developing comprehensive TPACK in educators requires balanced mastery of all its constituent domains. Integrating technological, pedagogical and content expertise creates a synergistic framework that is essential for effective teaching in technology-rich learning environments. However, the fact that only 18.75% of teachers are in the excellent category and 60% in the good category, while 21.25% of teachers are still in the moderate category, indicates that there is a significant group that has not achieved optimal competence in TPACK integration. This means that although statistically all components have a significant effect on TPACK, practically there are still about one-fifth of teachers, namely 21.25%, who have not been able to integrate TPACK effectively in learning practices. This group is a major concern because they have the potential to become obstacles to the digital transformation of education if they do not receive special interventions. In other words, statistical significance does not automatically mean that the entire teacher population has reached a high level of proficiency but there are still real challenges at the implementation level in the field, which is reflected in the data of 21.25% of Madrasah Tsanawiyah teachers with moderate proficiency.

DISCUSSION

The findings of this study corroborate and expand upon existing research on the Technological Pedagogical Content Knowledge (TPACK) framework, particularly in the context of Islamic education in developing regions, which has been under-explored to date. The distribution of TPACK mastery observed in this study:18.75% very good, 60% good and 21.25% moderate, aligns with that reported in similar studies. For example, Huriyah et al. (Huriyah et al., 2022) found comparable proportions of Madrasah teachers demonstrating foundational yet uneven competencies in East Java. This consistency highlights the broader challenges of technology integration in resource-constrained environments, where infrastructural limitations and fragmented professional development programmes impede comprehensive TPACK development. The TPACK framework's theoretical focus on the interdependence of technological, pedagogical, and content knowledge (J. B. Harris & and Hofer, 2011; Mishra & Koehler, 2006) is supported by the Structural Equation Modeling (SEM) results, which confirmed significant relationships between individual components (TK, PK, PCK, TCK, TPK) and overall TPACK mastery. However, by concentrating on Madrasah Tsanawiyah teachers who are often excluded from the global TPACK discourse this study uncovers contextual nuances that challenge universal assumptions regarding technology integration.

The reliance on basic digital tools, such as textbook images and whiteboards, mirrors findings by (Hanafi, 2023) in West Lombok Regency, where Madrasah teachers' technological practices remained rudimentary despite policy mandates advocating for digital transformation. This observation aligns with the broader literature highlighting technological tokenism in developing contexts, where educators adopt superficial digital practices due to gaps in training, confidence, and infrastructure (AlAli, 2024; J. Harris et al., 2009; Henriksen et al., 2024; Lane et al., 2023). However, this study diverges from previous research by emphasizing how Madrasah-specific curricular priorities, such as Islamic pedagogy, exacerbate these challenges. While generic TPACK models stress technological fluency, the integration of religious content with technology requires unique pedagogical strategies a dimension that remains underexplored in existing frameworks (Fasya et al., 2023; Timotheou et al., 2023). Thus, this study not only supports the core principles of the TPACK framework but also highlights its limitations in addressing culturally specific knowledge systems.

The SEM analysis, revealing TCK and TPK as pivotal mediators of TPACK mastery, corroborates (Martín Párraga et al., 2022; Pamuk et al., 2015; Viloria et al., 2019) assertion that integrative knowledge domains (e.g., TCK) outweigh isolated competencies (TK, PK) in predicting effective technology use. This challenges earlier assumptions that technological upskilling alone suffices for digital transformation (Aksin, 2023a; Rahayu et al., 2024), instead emphasizing the need for pedagogical and content integration. However, the study's context-specific findings contrast with research in high-income settings, where robust infrastructure and standardized training often mitigate such disparities(Ning et al., 2024; S. Zhang & Zhou, 2023). For example, while TPACK proficiency in Western contexts is frequently linked to institutional support and access to cutting-edge tools(J. Harris et al., 2009; J. B. Harris & and Hofer, 2011), this study identifies leadership engagement and culturally responsive mentoring as equally critical in Madrasah Tsanawiyah a nuance absent from dominant TPACK literature.

The hypothesis that holistic integration of TPACK components drives mastery more than individual proficiency aligns with An et al.'s (2023) argument for systemic professional development. However, this study uniquely identifies Madrasah teachers' generational divides as a moderating factor: millennial educators, despite greater technological literacy, often struggle to align digital tools with traditional Islamic pedagogies, whereas experienced teachers face steeper learning curves in adopting technology. This finding complicates the narrative that younger teachers inherently excel in TPACK (Sofwan et al., 2024), suggesting instead that balanced competency requires intergenerational collaboration and contextually adapted training-a gap in current TPACK models focused on individual rather than communal knowledge development (Gromik et al., 2024).

The study's emphasis on systemic barriers (e.g., infrastructural deficits, leadership support) reinforces (Gromik et al., 2024; Supraptoa et al., 2024) call for ecological approaches to TPACK development. Yet, it diverges by illustrating how Islamic educational philosophies-such as the prioritization of ethical and spiritual learning outcomes-reshape technology integration priorities. For instance, teachers in this study often prioritized digital tools that reinforced moral instruction over those fostering interactivity, a trend unaddressed in secular TPACK literature. This underscores the need to expand the framework's cultural dimensions, as current models inadequately account for non-Western pedagogical values(Machmud et al., 2022).

Finally, the observed moderate TPACK levels (21.25%) align with global post-pandemic trends, where the rapid adoption of digital tools has often outpaced pedagogical adaptation (Mansour et al., 2024; Ning et al., 2024; Valle et al., 2024). However, the study challenges the assumption that time and exposure alone can close these integration gaps. Instead, it underscores the continued importance of structured, iterative professional development a finding consistent with SEM-based research but frequently overlooked in policy frameworks that prioritize one-off training sessions (Kulaksız, 2023; Mourlam et al., 2021). By emphasizing the unique needs of Madrasah teachers, this study advocates for TPACK models that prioritize contextual relevance over standardization, offering a critical counterpoint to the universalist assumptions prevalent in educational technology discourse.

CONCLUSION

This study analyses the Technological Pedagogical Content Knowledge (TPACK) of learning among Madrasah Tsanawiyah teachers in Banyumas Regency, Indonesia. The results showed that although most Madrasah Tsanawiyah teachers had satisfactory levels of TPACK, their competence was not optimal. Only 18.75% of teachers showed excellent mastery of TPACK, while 60% were categorized as good, and 21.25% were still at a moderate level. Each TPACK component, namely Technological Knowledge (TK), Pedagogical Knowledge (PK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), and Technological Pedagogical Knowledge (TPK), was found to have a positive and significant influence on overall TPACK competence. However, 21.25 % of teachers at the moderate level indicate that a group of teachers have not effectively integrated TPACK into their teaching practices. This result shows that although the statistical analysis confirmed the positive influence of each TPACK component, the practical implementation in the classroom still faces challenges. The group of moderate-ability teachers should receive targeted support, as they are potential barriers to the success of the digital transformation of education in the Tsanawiyah Madrasah environment.

Several factors that influence the success rate of TPACK were identified, from rapid technological advancement, availability of learning apps, presence of younger teachers (millennial generation), support from school leadership, engagement in professional development and training, and adequacy of school infrastructure. In conclusion, while most Madrasah Tsanawiyah teachers in the Banyumas district demonstrate good TPACK, only a small proportion have reached a satisfactory level (excellent). This highlights the need for targeted mentoring, ongoing training, and further institutional support to improve teachers' competence in effectively integrating technology into the learning process.

The study has several limitations: it focused only on teachers in the Banyumas Regency, limiting the generalizability to other regions or educational institutions. The sample, while large (1,021 teachers), did not account for variations in gender, age, or teaching experience, nor did it explore differences in subject specialization or school resources. Additionally, using a standardized TPACK instrument may not fully reflect the context of Islamic education. The study was also limited to teacher learning, without considering technology tools or the school environment. Future research should expand the sample to multiple regions, include diverse demographic factors, and adopt a mixed-methods approach to provide more comprehensive insights and policy recommendations.

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