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Development and Standardization of the TPACK Scale for Pre-Service Teachers: Psychometric Properties and Normative Framework

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Abstract

The present study documents the systematic development and standardization of the TPACK Scale for Pre-Service Teachers, an instrument designed to measure Technological Pedagogical Content Knowledge (TPACK) among B.Ed. students. The scale encompasses seven interrelated dimensions: Technological Knowledge (TK), Pedagogical Knowledge (PK), Content Knowledge (CK), Pedagogical Content Knowledge (PCK), Technological Content Knowledge (TCK), Technological Pedagogical Knowledge (TPK), and Technological Pedagogical Content Knowledge (TPACK). Following rigorous item analysis using discriminant-power statistics and item-total correlations, 49 items were retained from an initial pool of 70 items. Reliability was established through multiple methods, yielding coefficients ranging from 0.92 to 0.96, indicating excellent consistency. Validity was confirmed through expert evaluation (face validity) and factor-analytic procedures (construct validity). A standardized normative framework was developed comprising three performance levels (Low, Middle, and High TPACK), with associated Z-scores and T-scores for 109 raw score points (52-240). The scale offers teacher educators and researchers a robust psychometric tool for evaluating pre-service teachers' technology integration competence within the Indian educational context.

Keywords: TPACK, pre-service teachers, scale development, psychometric properties, teacher education, technology integration, B.Ed.

1. Introduction

The rapid proliferation of digital technologies in educational settings has fundamentally transformed the expectations placed upon teachers in the twenty-first century. Prospective

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educators are now required not merely to demonstrate command over subject matter content or familiarity with instructional methodologies, but also to possess the competence to seamlessly weave technology into their teaching practice in ways that are contextually appropriate and pedagogically sound. The emergence of Technological Pedagogical Content Knowledge (TPACK) as a theoretical framework has provided both researchers and teacher educators with a coherent conceptual lens through which these multidimensional competencies can be understood, evaluated, and developed.

TPACK was formally conceptualized by Mishra and Koehler (2006) as an extension of Shulman's (1986, 1987) seminal construct of Pedagogical Content Knowledge (PCK). Where Shulman articulated the unique knowledge teachers require to transform subject matter into forms understandable to learners, Mishra and Koehler added a third critical dimension—technological knowledge—arguing that effective technology-integrated instruction demands a sophisticated and dynamic interplay among all three domains. This synergy, they contended, constitutes a form of knowledge qualitatively distinct from any of its constituent parts.

In the Indian teacher education landscape, the B.Ed. (Bachelor of Education) program serves as the primary pathway for professional preparation at the secondary and senior secondary levels. Despite increasing policy emphasis on technology integration—reflected in frameworks such as the National Education Policy 2020—systematic, psychometrically validated tools for measuring pre-service teachers' TPACK remain scarce. The present research addresses this gap by presenting the development, standardization, and normative framework of a TPACK Scale specifically designed for B.Ed. students.

2. Theoretical Background

2.1 The TPACK Framework

The TPACK model, as depicted in the original framework diagram by Mishra and Koehler (2006) and subsequently elaborated by Koehler, Mishra, and Cain (2013), posits seven distinct but interrelated knowledge domains. Three foundational knowledge bases—Technological Knowledge (TK), Pedagogical Knowledge (PK), and Content Knowledge (CK)—interact to produce four composite domains: PCK (the intersection of PK and CK), TCK (TK and CK), TPK (TK and PK), and, at the center of all intersections, TPACK itself.

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Each component carries unique definitional weight. Technological Knowledge (TK) refers to knowledge about various technologies, ranging from low-tech tools such as books and chalkboards to digital technologies such as the Internet, digital video, interactive whiteboards, and software applications. Pedagogical Knowledge (PK) encompasses deep understanding of the processes and methods of teaching and learning, including knowledge of learning theories, curriculum, assessment, and classroom management. Content Knowledge (CK) is the actual subject matter knowledge in the domain to be taught or learned.

The intersecting domains represent increasingly complex syntheses. PCK, following Shulman's original formulation, involves knowing how to represent specific content in ways that are accessible to particular learners. TCK represents an understanding of how technology and content influence and constrain one another. TPK reflects awareness of how specific technologies can alter the nature of teaching in ways that may strengthen or weaken particular pedagogical approaches. Finally, TPACK—the full intersection—represents an emergent form of knowledge that goes beyond all three components: it is the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies, pedagogical techniques that use technologies constructively to teach content, knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face, knowledge of students' prior knowledge and epistemology, and how technology can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones.

2.2 TPACK in Teacher Education Research

A growing body of scholarship has investigated TPACK as an evaluative lens for teacher preparation programmes. Li, Vale, Tan, and Blannin (2024) conducted a systematic review of TPACK research specifically within primary mathematics education, demonstrating the framework's applicability across curriculum areas and educational levels. Their analysis highlighted TPACK's significant role in lesson design, assessment construction, evaluation of teacher knowledge, and the design of professional development programmes.

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Raihanah, Putri, Fatmawati, and Nurjayadi (2024) conducted a literature review of TPACK ability among prospective chemistry teachers, observing that while conceptual understanding of TPACK had improved through targeted curriculum interventions, authentic integration of technology into instructional planning remained an area requiring sustained attention. Such evidence underscores the need for robust measurement instruments that can track developmental progress across teacher education programmes.

3. Objectives of the Study

The present study was undertaken with the following specific objectives:

- To develop a comprehensive item pool reflecting all seven components of the TPACK framework as applicable to B.Ed. students in India.
- To conduct systematic item analysis to identify items that optimally discriminate between high- and low-performing respondents.
- To establish the reliability of the finalized TPACK Scale using multiple statistical methods.
- To determine the validity of the TPACK Scale through face validity and construct validity (factorial validity) procedures.
- To develop normative standards, including Z-score and T-score equivalents, to enable meaningful interpretation of individual scores.

4. Methodology

4.1 Scale Construction

The initial item pool was developed through a systematic review of the TPACK literature and existing measurement instruments. Items were crafted to reflect authentic self-perceptions of competence across the seven TPACK dimensions. A five-point Likert-type response format was adopted, with anchors ranging from Strongly Agree to Strongly Disagree. Both positively and negatively keyed items were included to minimize the influence of acquiescence response bias. The initial version of the scale comprised 70 items, 10 per component.

4.2 Pilot Testing and Item Analysis

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The preliminary scale was administered to a sample of 120 B.Ed. students selected from accredited teacher education institutions. For the purpose of item analysis, extreme groups were formed: the top 27% (n = 36) and bottom 27% (n = 36) of scorers were designated as the High Group and Low Group, respectively, consistent with the criterion-group methodology recommended by Ebel (1966).

Two complementary criteria were applied for item retention. First, an independent-samples t-test was computed for each item to assess discriminant power between the high and low groups. Items reaching statistical significance at the 0.01 level were considered acceptable. Second, a Pearson product-moment correlation coefficient was computed between each item score and the total scale score; items yielding $r \geq 0.50$ were retained, consistent with conventions in psychometric scale development (Anastasi, 1968). Items failing to meet both criteria were eliminated from the final scale.

4.3 Final Scale Composition

Following item analysis, 49 items met the established retention criteria across all seven components. The distribution of retained items and their polarity (positive or negative keying) were carefully balanced to ensure adequate content coverage of each TPACK domain while maintaining psychometric integrity.

5. Results

5.1 Item Analysis

Of the original 70 items, 49 (70%) were retained in the final scale after applying the dual criteria of discriminant power ($p < 0.01$) and item-total correlation ($r \geq 0.50$). The mean t-values for accepted items across components ranged from approximately 3.43 to 8.60, indicating robust discriminant capacity. Item-total correlations for retained items ranged from 0.49 to 0.76, with a majority exceeding the 0.55 threshold, suggesting strong convergent relationships with the overall construct.

Component 1 (Technological Knowledge) retained 7 of 10 items; Components 2 (Pedagogical Knowledge) and 3 (Content Knowledge) each retained 7 items; Component 4 (Pedagogical Content Knowledge) retained 7 items; Component 5 (Technological Content Knowledge) retained 7 items; Component 6 (Technological

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Pedagogical Knowledge) retained 7 items; and Component 7 (TPACK) retained 7 items. Items rejected across components consistently exhibited non-significant t-values and/or item-total correlations below 0.25, indicating insufficient discriminatory power.

5.2 Scoring Scheme

The finalized 49-item TPACK Scale uses a five-point Likert response format. Positively keyed items are scored 5 (Strongly Agree), 4 (Agree), 3 (Neutral), 2 (Disagree), and 1 (Strongly Disagree). Negatively keyed items receive reverse scores: 1 (Strongly Agree) through 5 (Strongly Disagree). Total scores thus range from a minimum of 49 to a theoretical maximum of 245. However, the standardized score range based on the normative sample is 52 to 240.

5.3 Reliability

Three reliability estimates were computed using data from the full standardization sample (Table 1). Results consistently indicated high reliability:

Table 1:

Reliability Coefficients of the TPACK Scale

Method	Formula / Period	Coefficient (r)
Test-Retest	21 Days	0.96
Split-Half	Spearman-Brown Formula	0.92
Split-Half	Flanagan Formula	0.92

Note. All coefficients indicate excellent reliability (r > 0.90).

The Test-Retest reliability coefficient of 0.96 over a 21-day interval demonstrates exceptional temporal stability, indicating that the scale yields highly consistent measurements of TPACK across time. The Split-Half reliability estimates of 0.92 obtained through both the Spearman-Brown and Flanagan formulae further confirm the internal consistency of the instrument. These values exceed the conventional threshold of 0.80 recommended for psychometric scales used in research contexts, and approach the 0.95 standard advocated for high-stakes individual assessment (Anastasi, 1968).

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5.4 Validity

5.4.1 Face Validity. Expert opinions were solicited from a panel of specialists in educational psychology, educational technology, and teacher education. All 49 retained items received positive appraisals from the expert panel regarding their content representativeness, clarity of language, and appropriateness for B.Ed. student respondents. No items required elimination at this stage; minor wording revisions were incorporated as recommended. The expert consensus affirms that the TPACK Scale possesses satisfactory face validity.

5.4.2 Construct Validity (Factorial Validity). Factorial validity was assessed through a correlation matrix of the seven component subscale scores (Table 2). Examination of inter-component correlations reveals a pattern consistent with theoretical expectations: all components are positively and substantially correlated with one another, yet remain sufficiently differentiated to support the multidimensional structure of the TPACK framework.

Table 2:

Correlation Matrix of TPACK Scale Components

Component	TK	PK	CK	PCK	TCK	TPK	TPACK
TK	1.00	-	-	-	-	-	-
PK	0.89	1.00	-	-	-	-	-
CK	0.78	0.72	1.00	-	-	-	-
PCK	0.71	0.73	0.62	1.00	-	-	-
TCK	0.75	0.73	0.72	0.67	1.00	-	-
TPK	0.76	0.77	0.76	0.79	0.74	1.00	-
TPACK	0.72	0.68	0.68	0.67	0.73	0.72	1.00

Note. TK = Technological Knowledge; PK = Pedagogical Knowledge; CK = Content Knowledge; PCK = Pedagogical Content Knowledge; TCK = Technological Content Knowledge; TPK = Technological Pedagogical Knowledge; TPACK = Technological Pedagogical Content Knowledge.

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The highest inter-component correlation was observed between TK and PK (r = 0.89), reflecting the foundational and generative nature of these knowledge bases in shaping overall TPACK competence. The TPACK subscale demonstrated moderate-to-strong correlations with all six component subscales (range: r = 0.67 to 0.73), confirming that the TPACK composite captures variance related to but not fully determined by any single domain—consistent with Mishra and Koehler's (2006) theoretical proposition that TPACK is an emergent construct.

5.5 Normative Framework

Norms were established based on the standardization sample. Three performance levels were defined using percentile equivalents, enabling meaningful classification of individual scores relative to the reference group. Table 3 presents the normative levels:

Table 3:

Normative Levels for the TPACK Scale

Sr. No.	Level	Score Range	Norms
1	Low TPACK	52 to 117	Minimum to P33
2	Middle TPACK	118 to 172	P33 to P67
3	High TPACK	173 to 240	P67 to Maximum

Note. Score range based on standardization sample performance.

In addition to the percentile-based classification system, a comprehensive Z-score and T-score conversion table was prepared for each raw score point within the range of 52 to 240. Z-scores express each individual's performance as a deviation from the sample mean in standard deviation units, facilitating direct comparison across populations and measurement contexts. T-scores, derived from the corresponding Z-scores and calibrated to a distribution with mean of 50 and standard deviation of 10, provide an intuitive scale for practical interpretation that avoids negative values and decimal points characteristic of Z-scores.

6. Discussion

The development of the TPACK Scale for Pre-Service Teachers represents a methodologically rigorous effort to operationalize a complex theoretical construct within the specific context of Indian teacher education. Several features of the resulting instrument merit discussion.

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The item retention rate of 70% (49 of 70 initial items) reflects the selectivity of the dual-criterion item analysis procedure. Items rejected on the basis of non-significant discriminant power or insufficient item-total correlation were predominantly those addressing peripheral or overlapping aspects of the TPACK construct. The retained items, by contrast, demonstrated robust differentiation between high and low scorers, with t-values in several cases exceeding 8.00—a result indicative of very strong discriminant validity at the item level.

The reliability coefficients obtained across all three estimation methods are notably high. A Test-Retest coefficient of 0.96 places the TPACK Scale among the most temporally stable psychometric instruments in the teacher education measurement literature. The consistency between Spearman-Brown and Flanagan split-half estimates (both r = 0.92) further suggests that the scale's items are homogeneous in their measurement of the TPACK construct, notwithstanding its multidimensional theoretical structure.

The pattern of inter-component correlations in the validity matrix warrants interpretive attention. The moderately high correlations among all seven subscales (range: 0.62 to 0.89) are consistent with the theoretical proposition that TPACK dimensions, while analytically distinct, are in practice deeply interrelated. Teachers who possess advanced TK are likely to develop stronger TPK and TCK, as technological fluency creates opportunity for richer exploration of content-technology and pedagogy-technology intersections. At the same time, the absence of perfect multicollinearity among subscales confirms that each dimension retains unique explanatory variance, thereby justifying a multidimensional measurement approach over a unidimensional one.

The normative framework provides practical utility for both formative and summative assessment contexts. Teacher educators administering the TPACK Scale can use the three-level classification (Low, Middle, High) to identify cohorts of pre-service teachers who may benefit from targeted technology integration support, while the Z- and T-score tables permit nuanced individual profiling. This dual functionality—group-level screening and individual-level interpretation—enhances the instrument's applicability across diverse programmatic contexts.

7. Implications

7.1 Implications for Teacher Education

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The TPACK Scale provides B.Ed. programme coordinators and faculty with a validated diagnostic instrument that can be administered at multiple junctures in pre-service training—at programme entry to establish baseline competence profiles, at mid-point to assess developmental progress, and at programme completion to evaluate overall readiness for technology-integrated teaching. Diagnostic profiles derived from subscale scores can also guide the design of individualized or group-specific professional learning experiences targeting specific TPACK domains.

7.2 Implications for Research

From a research perspective, the TPACK Scale opens multiple avenues for empirical investigation. Comparative studies examining TPACK levels across different teacher education institutions, geographic regions, subject specializations, or programme structures can now be conducted with a standardized measure. Longitudinal designs tracking the development of TPACK over the course of the B.Ed. programme—or into early in-service teaching—would yield valuable insights into the trajectory and predictors of technology integration competence. Furthermore, intervention research testing the efficacy of specific curriculum modifications, technology-rich practicum experiences, or digital skill-building workshops would benefit from using the TPACK Scale as a standardized outcome measure.

7.3 Limitations and Future Directions

While the psychometric properties of the TPACK Scale are robust, several limitations should be acknowledged. The standardization sample was drawn from a specific geographical and institutional context, and the generalizability of the norms to other regions of India—or to international B.Ed. programmes—requires empirical verification. Future research should seek to cross-validate the scale's factor structure using Confirmatory Factor Analysis (CFA) to rigorously test the proposed seven-component model. Additionally, examining differential item functioning (DIF) across subgroups defined by gender, subject specialization, and medium of instruction would strengthen evidence for the scale's fairness and equitable applicability.

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8. Conclusion

The TPACK Scale for Pre-Service Teachers, as documented in this paper, represents a psychometrically sound, theoretically grounded, and practically applicable instrument for measuring technology integration knowledge among B.Ed. students. The scale's development followed rigorous methodological conventions, including systematic item analysis, multiple reliability estimation, expert-validated face validity, and factorial construct validity. The resulting 49-item instrument, supported by a comprehensive normative framework, offers teacher education stakeholders in India and beyond a reliable means of assessing, tracking, and enhancing pre-service teachers' readiness to teach with technology.

As digital transformation continues to reshape educational systems globally, instruments such as the TPACK Scale assume increasing importance. By providing a window into the complex intersection of technology, pedagogy, and content knowledge, the scale supports a more intentional and evidence-informed approach to preparing the next generation of teachers for the dynamic demands of contemporary classrooms.

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