Research On the Evaluation of TPACK Competence of Mathematics Normal Students Based on The Entropy Weight TOPSIS Model

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Abstract. In the context of educational informatization reform, the TPACK theory emphasizes the need for teachers to integrate subject knowledge, pedagogical knowledge, and technological knowledge. However, existing research methods are limited and lack depth. As future educators, mathematics teacher candidates urgently need to develop the ability to integrate information technology with teaching during their pre-service training to adapt to the demands of the times. Specifically, this study focuses on investigating the current status of TPACK competence among mathematics teacher candidates in teacher education colleges and exploring the influencing factors of TPACK competence. By utilizing the Schmidt scale and referencing multiple master's and doctoral theses, the study independently designs a questionnaire tailored to the characteristics of teacher education colleges. Using an entropy-weighted TOPSIS model to analyze the collected questionnaire data, this research aims to propose a TPACK competence evaluation model based on the unique features of higher education institutions. This approach not only enables a more accurate assessment of mathematics teacher candidates' TPACK competence but also provides a new research paradigm for other institutions of higher education.

Keywords: TPACK, Entropy weight improved TOPSIS model, Key factors, Ridit analysis model.

1. Introduction

In the context of the information age, the education sector is undergoing a transformation from traditional to digital modes, with emerging models such as online education and mobile education continuously appearing. The Ministry of Education of China has successively issued "Education Informatization 2.0" and "China Education Modernization 2035," emphasizing improving teaching quality supported by information technology, and has set clear requirements for teachers' information literacy through the "Standards for Information Technology Application Ability of Primary and Secondary School Teachers" [1]. The TPACK theory, proposed by Koehler and Mishra, emphasizes that teachers need to comprehensively master content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK), integrating them organically to enhance teaching effectiveness. However, current TPACK research mostly remains at the level of descriptive statistical analysis, with difficulty in determining indicator weights and insufficient scientific rigor in evaluation models. As an important reserve force for future teachers, mathematics normal students urgently need to cultivate the ability to integrate information technology and teaching during the pre-service stage to meet the demands of the times [2].

This study is based on the TPACK theoretical framework, combined with the Schmidt scale, multiple master's and doctoral theses, and the characteristics of surveyed institutions, to develop the "Survey on the Current Status of Information Literacy of Mathematics Normal Students from the Perspective of the 'TPACK' Theory." For the data obtained from the questionnaire, this research proposes an entropy weight improved TOPSIS model to conduct an overall assessment of the current status of TPACK, uses Spearman's coefficient for correlation analysis, ANOVA variance analysis for significance testing, conducts in-depth analysis of grade level, academic performance, competition and research experience with 7 TPACK derivative dimensions and 5 influencing factors of TPACK, and combines statistical results with an improved ridit analysis model,to identify 2 key influencing factors of TPACK.

2. Constructing a TPACK-Based Questionnaire

2.1. Determining the target respondents for the questionnaire

This study selected first- to fourth-year students majoring in Mathematics and Applied Mathematics (Normal) at the Teacher Education College of a university in Nanjing, with the survey conducted during the final stage of the second semester to improve the reliability of the questionnaire.

2.2. Completion of the Questionnaire Compilation

The process is mainly divided into three stages: questionnaire preparation, preliminary survey stage, and formal survey stage.

The questionnaire mainly consists of three parts: basic information, investigation of the current status of TPACK among mathematics teacher education students, and exploration of factors influencing the TPACK ability of mathematics teacher education students. The basic information is primarily designed based on the needs of this study and the author's own experience; the investigation of the current status of TPACK among mathematics teacher education students mainly refers to the design of previous questionnaires [3,4], and on this basis, some items that reduce the reliability and validity of this study were removed, and unclear items were specifically modified according to the author's environment. The TPACK of mathematics teacher education students mainly refers to five major influencing factors proposed by previous researchers: teacher professional identity factors, motivation and self-efficacy factors, educational technology course factors, teaching practice experience factors, and school resources and environment factors [5,6]. Based on these factors and combined with the characteristics of mathematics teacher education students at Nanjing Normal University, a self-designed questionnaire was developed.

2.3. Reliability and Validity Analysis of the Questionnaire

After collecting the data obtained from the questionnaire, a Likert five-point scale was used to score the five options of single-choice questions: strongly disagree 1 point, disagree 2 points, neutral 3 points, agree 4 points, strongly agree 5 points. SPSS 24.0 was used to conduct reliability and validity analysis.

2.3.1 Reliability Analysis of the Questionnaire

In terms of reliability testing, this research mainly used Cronbach's alpha coefficient for testing and conducted sensitivity analysis on each test item to ensure the reliability of the measurement results. The specific results are shown in the table 1:

Table.1. Summary of Cronbach's Alpha Coefficients

Indicator	Cronbach's alpha coefficient
TK	0.664
CK	0.625
PK	0.516
PCK	0.677
TCK	0.520
TPK	0.563
TPACK	0.608
Total scale	0.808

From the above summary table, this research found that the Cronbach's alpha coefficients of the 7 dimensions ranged between 0.520 and 0.677. According to the internal consistency criteria, the Cronbach's alpha coefficients of these 7 dimensions are all greater than 0.5, indicating good reliability. Moreover, the overall scale reliability reached 0.808, which is greater than 0.8, indicating very high scale credibility.

2.3.2 Questionnaire Validity Analysis

(1) KMO and Bartlett's Test of Sphericity

KMO and Bartlett's tests were applied to validate data suitability for factor analysis. KMO measures sampling adequacy via partial correlations (threshold >0.5), while Bartlett's test rejects the identity matrix hypothesis (p<0.05), confirming significant variable correlations. Collectively, these tests ensured foundational assumptions for subsequent analyses.

Table.2. Summary of KMO and Bartlett's Test of Sphericity Results

Indicator	KMO Value	Bartlett's Test of Sphericity		
		Approximate Chi-Square	df	p
TK	0.731>0.5	153.918	36	0.001
CK	0.590>0.5	89.177	36	0.001
PK	0.657>0.5	87.939	36	0.001
PCK	0.552>0.5	37.345	28	0.111
TCK	0.603>0.5	94.935	28	0.000
TPK	0.669>0.5	115.565	28	0.000
TPACK	0.750>0.5	196.179	28	0.000
Total scale	0.656>0.5	1572.417	741	0.001

From the above summary table 2, this research found that the KMO values of the 7 dimensions and the total scale are all between 0.552 and 0.731, greater than 0.5, with a sufficient sample size. The sphericity test, p=0.000<0.05, meets the sphericity test. Combining these two indicators, this case is suitable for factor analysis.

(2) Factor Analysis

Factor analysis extracted principal components to uncover latent structures in questionnaire items, aligning them with TPACK theoretical dimensions. By quantifying item contributions to each dimension, it validated the construct validity and established a robust basis for further research.

Table.3. Total Variance Explained (Partial)

	Initial Eigenvalues			Sum of Squared Loadings Extracted			Sum of squares of rotational loads		
Component	Total	Percentage of variance	Cumulative %	Total	Percentage of variance	Cumulative %	Total	Percentage of variance	Cumulative %
1	5.14	21.40	21.40	5.14	21.40	21.40	3.72	15.51	15.51
2	4.32	18.01	39.40	4.32	18.01	39.40	2.81	11.72	27.23
3	2.01	8.37	47.78	2.01	8.37	47.78	2.50	10.43	37.67
4	1.79	7.44	55.21	1.79	7.44	55.21	2.38	9.93	47.59
5	1.60	6.67	61.88	1.60	6.67	61.88	2.13	8.86	56.45
6	1.15	4.81	66.69	1.15	4.81	66.69	2.07	8.61	65.06
7	0.96	4.01	70.70	0.96	4.01	70.70	1.35	5.64	70.70

Through the table 3, this research found that the cumulative contribution rate of the extracted 7 principal components reached 70.7%, indicating a good factor analysis effect. Furthermore, this research analyzed the rotated component matrix and conducted a confirmatory analysis of the questionnaire's structural validity. The results showed that the rotated component matrix of the 24 questions exactly corresponded to the 7 components, and the questions within each component met the expected design, thus the questionnaire has good structural validity.

3. Construction of the TPACK scoring model

The TOPSIS method is an effective multi-criteria evaluation approach. This method constructs the positive ideal solution and negative ideal solution for the evaluation problem, that is, the optimal and worst solutions for each criterion. By calculating the relative closeness of each scheme to the ideal solution, i.e., the degree to which it is close to the positive ideal solution and far from the negative ideal solution, the schemes are ranked to select the best one [7]. This study uses the entropy weight method improved TOPSIS model to evaluate and analyze the data [8].

3.1. Determining the Weights of the 7 Major Indicators Using the Entropy Weight Method

The traditional TOPSIS model uses equal weighting to determine weights, whereas by using the entropy weight method, the weights of each attribute in the model can more objectively reflect their importance. This study applied the entropy weight method to data collected from 7 indicators to determine the weights, with the specific results shown in the table 4:

Table.4. Weights of the 7 Indicators Determined by the Entropy Weight Method

Indicator	Weight
TK	0.14
CK	0.08
PK	0.12
PCK	0.15
TCK	0.21
TPK	0.14
TPACK	0.14

3.2. Construction of TPACK Competency Scoring Model Using TOPSIS Method

Scores for each sub-question under each primary dimension were obtained through a five-level Likert scale, then averaged and weighted summed to get the primary dimension score for each questionnaire, namely:

$$X_iK = \frac{\sum_{i=1}^{n} X_iK - score}{n} (X_i = T、C...) \tag{1}$$

Partial results of students' total TPACK scores: Using the TOPSIS model combined with the entropy weight method, the seven primary dimensions in the second part of each questionnaire are summed to obtain the total TPACK score for each questionnaire, facilitating subsequent related analyses.The specific results are shown in the table 5:

Table.5. Partial Results of Students' Total Scores

Questionnaire Number	TPACK Total Score
1	0.563
2	0.851
3	0.329
4	0.489
5	0.621

4. Results

4.1. Overall status results and correlation analysis of TPACK

4.1.1 Overall result analysis

By observing the overall data, this research found that the total TPACK scores of male and female students are relatively close (male: 0.573, female: 0.504). However, for grade level (freshman: 0.482, sophomore: 0.548, junior: 0.674, senior: 0.667), academic performance (below 5%: 0.893, 5%-30%: 0.745, 31%-60%:0.459, 61%-100%: 0.421), and total competition scores (2–3: 0.442, 4–5: 0.557, 6–7: 0.897, 8: 0.986), there is a clear correlation with the average TPACK total score. To further analyze the strength of these correlations, this research notes that grade level, academic performance, and competition and research experience are all ordinal variables, meeting the conditions for Spearman correlation analysis, and there is no need to consider whether the variables follow a normal distribution. Therefore, this research uses the Spearman coefficient to analyze the correlations of these three attributes, as shown in table 6:

Table.6. Overall Spearman Correlation Analysis Results

Correlation Coefficient	TPACK Total Score	Grade	Major Academic Performance	Competition and Research Experience
TPACK Total Score	1.00	0.832	0.711	0.867
Grade	0.832	1.00	0.523	0.704
Major Academic Performance	0.711	0.523	1.00	0.851
Competition and Research Experience	0.867	0.704	0.851	1.00

From the results in the above table, it can be seen that for the total TPACK score, the correlations from strongest to weakest are: competition and research experience, grade level, and academic performance. This research believes that competition and research often require the use of information technology, Exercise leads to becoming the innovation point of many works; the characteristic of the mathematics major courses offered by the school's teacher training institute lies in: from the second year onwards, gradually offering mathematics application courses and educational information technology courses. There is a positive correlation between grade level and the overall TPACK score, which indeed confirms the rationality of the courses offered by the college; in addition, students with good professional grades, on the one hand, may have a firmer grasp of knowledge and skills in information technology-related courses, and on the other hand, have more free time to engage with related information technology.

4.1.2 Detailed Analysis of Each Dimension

(1) Grade Level

In the overall analysis, this research found that the total TPACK score is correlated with grade level, academic performance, and competition and research experience. Furthermore, this research conducted Spearman correlation analysis and one-way ANOVA on the seven primary indicators under the total TPACK score dimension with these three factors to fully explore the data value.

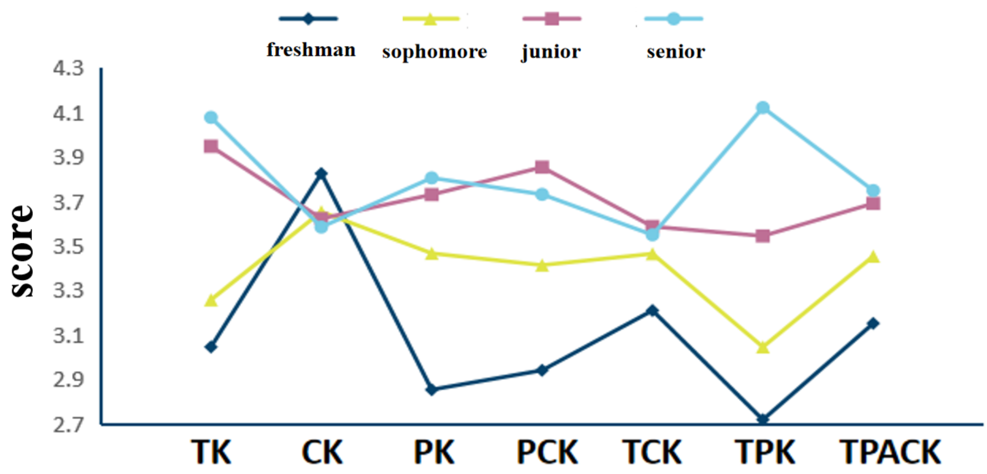

Figure 1. Comparison Chart of TPACK Scores Across Different Dimensions by Grade Level

From the TPACK score statistics of each grade in the Figure 1 above, it is not difficult to find: the higher the grade, the greater the TK, the smaller the CK, the greater the PK, and the greater the TPACK. There are significant differences between freshmen and sophomores and juniors and seniors in terms of TK and PK. TPK increases with grade level and shows a significant increase in the senior year. PCK and TCK reach their highest scores in the junior year and decline in the senior year. Furthermore, this study analyzed their correlations using the Spearman coefficient.

Table.7. Dimensions Correlated with Grade and Correlation Coefficients

Indicator dimensions	Spearman correlation coefficient
TK	0.911
CK	-0.821
PK	0.879
TPK	0.934
TPACK	0.883

From above table 7, it can be seen that TK, PK, TPK, and TPACK are positively correlated with grade level; the higher the grade, the higher the average score for these items. Moreover, the correlation coefficients for TK and TPK are very high, which undoubtedly indicates that the information technology courses offered by the Teachers College have played their due role, not only promoted students' information literacy but also enabled students to integrate information technology with education. However, CK is negatively correlated with grade level, which to some extent reflects that as the grade increases, normal students tend to forget their basic mathematics knowledge, focusing more on application and less on fundamentals. This also warns the college to pay attention to cultivating students' basic mathematics knowledge.

In addition, in the line chart, this research found a significant difference between TK and PK, so ANOVA variance analysis was used to further explore the internal relationship.

Table.8. ANOVA Descriptive Results — TK Scores

Grade	TK Mean	TK Standard	Homogeneity of variance test - Significance	ANOVA	
				F	Significance
Freshman	3.046	1.306	0.692>0.05	7.905	0.001<0.05
Sophomore	3.258	1.331			
Junior	3.948	1.459			
Senior	4.078	1.441			

From above table 8, this research found through homogeneity of variance test that the p-value is greater than 0.05, so the variances of the three groups are equal, allowing for subsequent variance analysis. ANOVA variance analysis confirmed significant differences in TK scores among the four grades, but which groups differ from each other is still unclear, thus further pairwise comparisons are needed. Here, this research chose the SNK method for comparison [9], which uses the t-range distribution to perform pairwise comparisons between means, and employs a stepwise procedure to compare means within homogeneous subsets of equal sample size. Means are arranged from high to low, first testing the extreme difference values.

Table.9. SNK homogeneous subset results display — TK scores

Grade (α = 0.05)	1	2
Freshman	3.046	
Sophomore	3.258	
Junior		3.948
Senior		4.078
Significance	0.252	0.357

From above table 9, it can be seen that SNK considers that in terms of TK scores, the grades can be divided into two groups: freshmen and sophomores as one group, juniors and seniors as another group. This indicates that there is no significant difference in TK ability between freshmen and sophomores, and no significant difference in TK ability between juniors and seniors. However, there is a significant difference between the groups of freshmen and sophomores versus juniors and seniors. This research reviewed the courses offered by the Teachers College and found that during the sophomore and junior years, students successively studied courses such as Modern Educational Technology, Computational Methods, Numerical Solutions of Differential Equations, and Middle School Mathematics Teaching Design and Skills Training, which significantly improved the students' TK ability.

Table.10. ANOVA Descriptive Results—PK Scores

<table>
<tr><th rowspan="2">Grade</th><th rowspan="2">PK Mean</th><th rowspan="2">PK Standard</th><th rowspan="2">Homogeneity of variance test - Significance</th><th colspan="2">ANOVA</th></tr>
<tr><th>F</th><th>Significance</th></tr>
<tr><td>Freshman</td><td>2.854</td><td>1.406</td><td rowspan="4">0.741>0.05</td><td rowspan="4">9.459</td><td rowspan="4">0.001<0.05</td></tr>
<tr><td>Sophomore</td><td>3.467</td><td>1.382</td></tr>
<tr><td>Junior</td><td>3.731</td><td>1.301</td></tr>
<tr><td>Senior</td><td>3.806</td><td>1.311</td></tr>
</table>

Table.11. SNK Homogeneous Subset Results Display—PK Scores

Grade	Alpha subset = 0.05	
	1	2
Freshman	2.854	
Sophomore	3.467	
Junior		3.731
Senior		3.806
Significance	0.483	0.425

From the table 10 and table 11 above, after conducting the same analysis as in the previous text, it is evident that during the junior and senior years, PK ability significantly improves. This research mainly considers that students in the teacher training college need to complete educational internships in their junior year and have started the teacher qualification examination, and in the senior year, they complete educational internships. These aspects can significantly enhance students' teaching abilities.

(2) Professional Grades

After performing similar work as with the grade level, this research found that professional grades have a positive influence relationship with CK, PCK, TCK, and TPACK, and there is no significant difference. This research believes that when professional grades improve, subject knowledge will definitely improve, thereby leading to improvements in all C-related indicators.

(3) Competition and Research Experience

Since this research considers that with the advancement of grade level, the enrichment of competition and research experience will increase to some extent, directly using Spearman correlation analysis and ANOVA variance analysis as before would lead to inaccurate results. Therefore, this research uses Spearman partial correlation analysis here, first excluding the influence caused by grade level. The results are shown in table 12 below.

Table.12. Spearman partial correlation analysis results of competition and research experience

Control Variables	Analytical Variables	Correlation Coefficient	Significance
Grade	TK	0.699	0.001
	TCK	0.657	0.001
	TPACK	0.602	0.003

After Spearman partial correlation analysis, all correlation coefficients decreased. This research considers a correlation coefficient > 0.6 to indicate correlation. Therefore, a total of competition and research experience and TK, TCK, and TPACK show a positive influence relationship. This research believes that in competitions and research, frequent use of computer information network technology can effectively improve students' information literacy, thereby bringing improvements to various T-related indicators.

4.2. Analysis of Important Influencing Factors of TPACK

4.2.1 Overall Results Presentation

Table.13. Overall Results of TPACK Influencing Factors

	Mean	Standard Deviation
V30 (Educational Technology Course Factor)	3.4	1.346
V31 (Educational Technology Course Factors)	3.34	1.331
V32 (School Resources and Environment Factors)	3.41	1.187
V33 (School Resources and Environmental Factors)	3.16	1.237
V34 (Professional Identity Factors)	3.56	1.291
V35 (Professional Identity Factor)	3.24	1.371
V36 (Motivation and Self-Efficacy Factor)	3.49	1.322
V37 (Motivation and Self-efficacy Factors)	3.39	1.364
V38 (Teaching Practice Experience Factor)	3.38	1.316
V39 (Teaching Practice Experience Factor)	3.26	1.319

4.2.2 Correlation Analysis

From above table 13, through Spearman correlation analysis, this research mainly obtained the following conclusions: grade level and teaching practice experience factors have a positive influence on professional identity factors; professional grades and motivation and self-efficacy factors, professional identity, and educational technology course factors have a positive influence; research and competition experience have a positive influence on motivation and self-efficacy factors and a negative influence on educational technology course factors.

4.2.3 Improved ridit method to identify key factors

Based on the results collected from the questionnaire, it can be intuitively observed that most mathematics teacher education students believe that motivation and self-efficacy factors, professional identity factors, and educational technology course factors play a significant role in the cultivation of

TPACK ability. Meanwhile, this research believes that attention should be paid to the differences in students' choices for the same question options; the greater the differentiation, the more attention the school should pay. Current education advocates personalized development, and everyone's views should be valued. Therefore, this research improved the ridit analysis method [10], assigning scores to the significance coefficients obtained from ridit analysis for each group and summing the scores and variances with equal weights to obtain ridit scores, which were then ranked from high to low. The higher the score, the more obvious the differentiation of the factor options, and the more worthy of our attention. The results are shown in the following table.14:

Table.14. Summary of ridit scores

Factors influencing TPACK	Ridit Score	Confidence Interval		W Value	P Value
Motivation and self-efficacy factors	0.7143	0.6735	0.7551	38.23	7.872e-08
Educational technology course factors	0.7029	0.6621	0.7434		
Teaching practice experience factors	0.6566	0.6974	0.7382		
School resources and environmental factors	0.6114	0.5706	0.6232		
Sense of professional identity factors	0.5824	0.5416	0.6232		

Result analysis: From the results in above table 14, the overall ranking is generally consistent with the variance ranking shown in the previous overall results. Except for the significant change in the ranking of the sense of professional identity, the rankings of other factors remain stable. This indicates that motivation and self-efficacy factors, as well as educational technology course factors, are urgently in need of attention from both group and individual perspectives. Here, this research refers to these two as key factors.

5. Conclusions

This study constructed a TPACK evaluation framework for pre-service mathematics teachers using the entropy-weighted TOPSIS model. Empirical analyses revealed that TPACK competence correlates significantly with grade level, academic performance, and competition/research engagement, with the latter exerting the strongest influence. Key drivers identified through an improved ridit model include self-efficacy and educational technology training. These findings validate the model’s applicability in educational evaluation and offer actionable insights for teacher training programs.

Limitations, such as single-institution sampling, suggest future research should expand to cross-regional and interdisciplinary cohorts, integrate longitudinal tracking, and combine qualitative methods like interviews. The proposed framework demonstrates broader potential in evidence-based educational assessments, shifting from subjective to data-driven weight allocation, thereby enhancing objectivity in teacher development and curriculum evaluation.

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