Structural Analysis of the Chinese Framework for Digital Literacy of Teachers: Based on PLS-SEM

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Abstract. The Chinese Ministry of Education introduced a Chinese framework for teachers' digital literacy in 2022 to guide digital literacy development. However, the Chinese framework lacks applicable measurement scales. This study transformed descriptions of the Chinese framework into a scale, examined the rationality of its structure, and attempted to explore the approaches to improve the scale. Data were collected from 370 pre-service English teachers in a city in Central China through a questionnaire. Based on the PLS-SEM analysis, the results showed that the scale showed satisfactory reliability and validity; yet, the results unveiled structural problems of the scale. Therefore, it is important to establish theoretical structure of each construct, and then refine the scale by the supplementation of certain items.

Keywords: digital literacy of teachers, CTA-PLS, PLS-SEM

1 INTRODUCTION

Teachers and teacher educators have experienced increasing access to various digital tools and resources in recent years. Recent research revealed that teachers' digital literacy in their roles as qualified teachers is important for the development of professional teacher competence[1]. Given the importance of teacher digital literacy in teachers' professional competence, digital literacy of teachers has gained strong prominence in research on teacher education[2,3]. In this regard, several models and frameworks developed by different countries to emphasize the crucial role of digital literacy to teacher competence. The most widely adopted two frameworks of teachers' digital literacy are the European Framework for Digital Competence of Teachers defined by European Union[4] and the Digital Literacy of Teachers released by the Chinese Ministry of Education[5] (the Chinese framework in this study).

The European framework defines teacher digital literacy as educator-specific digital competences in undertaking teachers' professional activities[4]. Whilst, the Chinese framework defines teacher digital literacy as digital awareness, digital technology knowledge and skills, digital application, digital social responsibility, and professional development[5]. Under the Chinese framework, there are five first-order dimensions

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which consist of 13 second-order dimensions and 33 third-order dimensions. However, there is no corresponding measurement based on this framework, which poses a pressing challenge that must be addressed. According to the Chinese framework, the descriptions of teachers' digital literacy can be directly transformed into scale items, with the summation of scores of these items serving as the score of teachers' digital literacy. However, this approach fails to capture the hierarchical structure of the Chinese framework and makes it difficult to evaluate distinct literacy individually. Thereby, this study aimed to explore the following research questions: How to evaluate the structure of the scale derived from the Chinese framework? What improvements are needed to make the measurement of Chinese teachers' digital literacy reasonable?

2 RESEARCH METHODS

2.1 Research Design

In line with the research question, a scale based on the Chinese framework was developed. After data collection, an analysis of the structure of the scale was conducted to analyze its validity.

2.2 Instrument

According to the research design, the descriptions of teachers' digital literacy in the Chinese framework were directly translated into scale items. Due to a one-to-one correspondence between the descriptions and the third level dimensions, and the common occurrence of fewer than three items under the second level dimensions, the scale structure was simplified to a reflective-reflective second-order structure. In this structure, the descriptions of the third level dimensions are the items of the second order constructs, and the factors of the first level dimensions are the second order constructs.

2.3 Participants

The participants were English major students from four universities (in the third and fourth grades) in a city in central China. They were actively engaged as pre-service English teachers. The rationale for selecting participants predominantly revolves the notion that participants of the same major can effectively avoid sample heterogeneity. Moreover, participants' digital literacy was primarily derived from professional education during university, rather than being influenced by other fields of study like physics or mathematics. Given the quantity of scale items and the methodological requirements for data analyses, the number of participants was recommended to be between 5 to 10 times the number of scale items[6]. Ultimately, 370 valid data were collected. Among them were 319 female and 51 male participants, aged between 18 and 25 years old.

2.4 Data Analysis

Data analysis is mainly divided into three parts: First, a Confirmatory Factor Analysis (CFA) was conducted to examine whether the reliability and validity of the first-order construct of the scale aligned with the structure of the Chinese framework. If the CFA results were unsatisfactory, further exploration of a potentially reasonable scale structure was necessary. Thus, an Exploratory Factor Analysis (EFA) was required to examine the structure of the scale under data-driven conditions. Finally, confirmatory tetrad analysis in PLS-SEM (CTA-PLS), an analysis of the measurement models for both the first-order and second-order scales, was conducted to determine whether the scale model was reflective or formative[7].

3 RESULTS

3.1 The Results of CFA

When conducting CFA on the five constructs using a reflective structure, it is necessary to examine their convergent validity, discriminant validity, and model fit. Convergent validity requires the examination of several indicators, including standardized outer loading, Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE). The loading values for items DLT (digital literacy of teachers)01, 02, 06, 21, 22, and 28 did not meet the cutoff value of 0.7, while the remaining items met the requirement. The Cronbach's α and CR values for the five constructs exceeded the cutoff value of 0.7, and the AVE surpassed the cutoff value of 0.5, indicating acceptable reliability and validity of the scale. Discriminant validity was assessed by examining the Heterotrait-Monotrait Ratio of Correlations (HTMT), with all HTMT values falling below 0.9 and the confidence interval (CI) not including 1, indicating good discriminant validity. The evaluation of model fit involved in the model fit test was relatively complex. In this study, we referred to the relatively loose standards proposed by Schermelleh-Engel et al[8]. As shown in Table 1, the model exhibits poor fit, suggesting that there might be some problematic issues within the theoretical structure of the scale.

Table 1. The results of model fit

	χ^2	χ^2/df	RMSEA	SRMR	TLI	CFI
Criteria		<3	<0.08	<0.08	>0.95	>0.9
Value	1522.356	3.139	0.076	0.057	0.877	0.887

Abbreviations: RMSEA, root mean square error of approximation; SRMR, standardized root mean square residual; TLI, Tucker-Lewis Index; CFI, comparative fit index.

3.2 The Results of EFA

The results of the EFA indicated a Kaiser-Meyer-Olkin (KMO) index of 0.958 for the measure of sampling adequacy, and Bartlett's test of Sphericity was significant at the

0.001 level, affirming the suitability of the data for factor analysis. By using the extraction method, combining principal axis factoring and the rotation method of Oblimin with Kaiser normalization., the results showed that all loadings satisfied the threshold values recommended by Hair[7]. Additionally, the EFA revealed the emergence of 5 distinct factors comprising 33 items, explaining 68.985% of the variance. The structures of the constructs digital awareness, digital social responsibility, and professional development aligned with the original theoretical intention of the scale; however, DLT06 did not load significantly onto any factor, DLT07 to 16 clustered into one factor, and DLT17 to 22 grouped into another factor, indicating substantial deviations from the original structure. Due to space limitations, the complete CFA and EFA results are provided in the supplementary materials (https://drive.google.com/file/d/1pdUWXdblV5KT5LXoK3f527YUX5OvMHzH/view?usp=sharing).

3.3 The Results of CTA-PLS

Except the theoretical underpinning, CTA-PLS is considered a more robust statistical method for the determination whether the latent or higher-order construct is reflective or formative[7]. This methodology involves assessing construct indicators in a tetrad form. If the number of the significant tetrad values is more than 80%, suggesting that the construct is formative[9].

The results further showed that among the five first-order constructs, digital technology knowledge and skills had only three indicators, making analysis unfeasible. The number of significant tetrad values for digital awareness, digital application, and professional development were all below 80%, suggesting that these constructs are reflective. However, the number of tetrad values for digital social responsibility exceeded 80%, suggesting it is a formative construct. Specific results are detailed in Table 2. Following the conversion of digital social responsibility into a formative variable, a second-order CTA-PLS analysis was conducted using the latent variable scores of each construct. The results indicated that the second-order constructs were reflective in nature, but the loading values for the digital social responsibility construct did not meet the threshold.

Table 2. The results of confirmatory tetrad analysis

Tetrad - digital social responsibility	Original Value
1: DLT23,DLT24,DLT25,DLT26	0.134*
2: DLT23,DLT24,DLT26,DLT25	0.176**
4: DLT23,DLT24,DLT25,DLT27	0.187**
6: DLT23,DLT25,DLT27,DLT24	0.052
7: DLT23,DLT24,DLT25,DLT28	0.120*
10: DLT23,DLT24,DLT26,DLT27	0.295***
16: DLT23,DLT24,DLT27,DLT28	0.318***
22: DLT23,DLT25,DLT26,DLT28	0.157**
26: DLT23,DLT25,DLT28,DLT27	0.170**

Notes: *p < 0.05, **p < 0.01, ***p < 0.001

4 DISCUSSION

The results of the CFA showed that the scale had satisfactory reliability and validity; however, the model fit was neither good nor acceptable, and some items had loading problems. These results indicate that there is ample room for improvement in the items of this scale, suggesting the need for item supplementation in statement formulation in further scale revisions.

The results of the EFA showed that the stability of the constructs, such as digital awareness, digital social responsibility, and professional development, has been confirmed. The items effectively capture the theoretical conceptions of these three constructs. However, the items of the constructs of digital technology knowledge and skills and digital application could not be divided as theoretically expected, suggesting a potentially stronger relationship between digital technology knowledge, skills, and application than originally anticipated. Hence, a reevaluation of the relationship between these two constructs is warranted in further scale revisions.

The results of CTA-PLS showed that among the first-order constructs, the construct - digital social responsibility- was a formative construct; while the remaining constructs were reflective constructs. About the second-order constructs, all were reflective constructs; however, the loading of the items in the construct of digital social responsibility was problematic. These findings indicate that adjustments to the digital social responsibility construct are necessary. It is essential to note that the outcomes of CTA-PLS are merely statistical, and the selection of measurement models should primarily adhere to theoretical requirements. In future research, it may be imperative to involve experts to perform a theoretical analysis of measurement models initially.

5 CONCLUSION

The current study revealed that developing a scale directly from the descriptions derived from the Chinese framework resulted in a scale demonstrating overall satisfactory reliability and validity. However, certain items within constructs and the interrelationships among constructs need to be refined to ensure coherence and adherence to the theoretical underpinnings of the Chinese framework. Notably, the measurement model requires a comprehensive examination of whether constructs at varying levels are reflective or formative, which should incorporate both theoretical deliberation and statistical analysis to ascertain the optimal measurement model. While the current scale is functional without delving into specific sub-dimensions, there remains considerable room for improvement. Future research endeavors can address these issues through targeted revisions of the scale.

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