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RESEARCH ARTICLE

# Evaluating Digital Competence: An Examination of Secondary School Teachers in China

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**Abstract:** In recent years, the Chinese government has actively promoted the digital transformation of education, with a strong emphasis on integrating digital technologies into teaching practices. As a result, teachers' digital competence has become a key focus of academic research. This study surveyed secondary school teachers in mainland China using the Teacher Digital Competence Self-perception Instrument, and descriptive statistical analysis and inferential statistical analysis were conducted on the data. The findings indicate that teachers generally have a positive self-perception of their digital competence. However, they demonstrate weaker skills in digital teaching and learning management, while excelling in digital engagement. Significant differences in digital competence were observed based on teaching experience, educational background, and regional disparities. To address these challenges, China should offer more professional development opportunities for teachers and enhance policy support for improving digital competence. These findings and recommendations may provide useful insights for other countries and regions pursuing similar initiatives.

**Keywords:** evaluate, digital competence, secondary school teacher, professional development, digital transformation

## 1. Introduction

The digital competence of teachers is pivotal to the successful digital transformation of education. Teachers have the potential to leverage a wide range of online platforms and applications to diversify learning pathways, thereby enhancing student engagement and interaction. Furthermore, digital tools such as educational data analysis and assessment software enable teachers to gain more comprehensive insights into student learning progress and needs, facilitating personalized support and guidance.

The COVID-19 pandemic, which emerged in 2020, underscored the indispensable role of digital technologies in education. This global crisis necessitated a fundamental shift in students' learning methods and teachers' instructional approaches. In China, the restrictions on traditional face-to-face teaching compelled secondary school teachers to swiftly adopt and adapt to digital technologies and tools, transitioning to online modes of instruction. Consequently, this rapid digital shift has required teachers to rethink and modify their pedagogical approaches to align with students' learning demands in a digitally mediated environment.

While the proliferation of digital technologies in education has equipped teachers with new pedagogical tools, it has also heightened the expectations for their digital competence. Despite this growing reliance on technology, many teacher education programs have not provided adequate preparation for the integration of digital tools into teaching practice [1]. Therefore, assessing teachers' digital competence and identifying gaps in their skills are essential steps in informing targeted professional development and fostering their ability to meet the challenges of digital education.

## 2. Literature Review

Digital competence is defined as "the set of knowledge, skills, attitudes (including abilities, strategies, values, and awareness) required to effectively use Information and Communications Technology (ICT) and digital media to perform tasks, solve problems, communicate, and manage information, among other functions" [2]. This comprehensive definition has been widely adopted in academic research [3–5]. Building upon this concept, scholars have tailored the definition of teacher digital competence (TDC) to the specific professional context of teaching, describing it as the set of knowledge, skills, and attitudes that enable teachers to effectively integrate ICT in supporting student learning [6].

A central focus in research on TDC is the development of valid measurement tools. In 2019, Ghomi and Redecker [7] designed a 22-item self-assessment scale based on the DigCompEdu framework [8], revealing significant differences in digital competence between STEM and non-STEM teachers. Subsequent applications of this scale located university professors in Brazil at level B1 in their self-perceived digital competence [9], indicating a moderate level of digital teaching competence [10]. In addition, several studies have utilized the Common Digital Competence Framework for Teachers to assess TDC [11–13].

In the context of China, quantitative studies indicate that primary and secondary school teachers possess moderate levels of

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digital literacy [14], with survey-based research further revealing that in-service teachers demonstrate higher digital competence than pre-service teachers [15]. In Macau, English teachers reported the highest levels of self-perceived competence in selecting digital resources, but the lowest in digital assessment strategies [16]. One limitation in quantitative studies on TDC is the small sample sizes used [17]. Moreover, considering the substantial economic disparities across eastern, central, and western China, the impact of regional differences on TDC remains underexplored.

This study aims to address these gaps by conducting a large-scale quantitative survey to investigate the digital competence of secondary school teachers through an expanded survey sample. By examining the current state and variations in digital competence across different teacher subgroups, this research seeks to identify the key challenges hindering teachers' digital competence and propose targeted recommendations to support their professional development.

## 3. Methodology

This study adopts a quantitative research approach, utilizing a self-perception scale to measure digital competence. The analysis focuses on examining the relationship between secondary school teachers' sociological background characteristics and their levels of digital competence, as revealed by the data collected.

### 3.1. Participants

A random sampling survey was conducted among teachers using an online questionnaire. Data collection occurred over two months between March and April 2023. The initial screening involved the use of reverse-coded items to ensure data integrity, followed by the exclusion of responses with uniform answers throughout or where more than half of the responses were identical.

A total of 745 valid questionnaires were retained for analysis. While this number may not seem large relative to the vast population of secondary school teachers in China, due to the time constraints of the survey and its nature as a phased initiative, the 745 valid questionnaires are sufficient to meet the requirements for data analysis. The sample encompassed teachers from 28 of the 34 provincial-level administrative regions in mainland China. To examine regional differences in teachers' digital competence, the location of the schools where the respondents worked was categorized into eastern, central, and western regions, following the classification standards of the National Bureau of Statistics of China. Given the small number of teachers with associate and doctoral degrees, these groups were combined with bachelor's and master's degrees, respectively, resulting in two educational attainment categories: graduate-level and above and bachelor's degree or below. Descriptive statistics of the sample's sociological background characteristics are presented in Table 1.

**Table 1**
**Distribution of sample characteristics**

| Category | Subgroup | Quantity | Proportion/% |
|---|---|---|---|
| Gender | Male | 185 | 24.832 |
| | Female | 560 | 75.167 |
| Teaching stage | Middle school | 267 | 35.839 |
| | High school | 478 | 64.161 |
| Education background | Diploma | 1 | 0.134 |
| | Bachelor | 483 | 64.832 |
| | Master | 255 | 34.228 |
| | PhD | 6 | 0.805 |
| Years of teaching | –3.99 | 137 | 18.389 |
| | 4.0–6.99 | 86 | 11.543 |
| | 7–18.99 | 318 | 42.685 |
| | 19–30.99 | 156 | 20.94 |
| | 31– | 48 | 6.442 |
| Professional title | Junior | 195 | 26.174 |
| | Intermediate | 408 | 54.765 |
| | Senior | 133 | 17.852 |
| | Distinguished senior | 9 | 1.208 |

### 3.2. Instrument

This study utilizes the Teacher Digital Competence Self-perception Instrument (TDCSI) as the measurement instrument, comprising 24 items across six domains, including digital ethics and safety, as well as digital engagement (see Figure 1). Although Yan et al. [18] previously created a questionnaire to evaluate ICT competence among Chinese primary and secondary school teachers, it was based on the Information Technology Application Competence Standards (Trial Version) issued by the Chinese Ministry of Education in 2014. Given the rapid technological advancements and evolving understanding of information technology over the past decade, the previous questionnaire may no longer adequately reflect current practices and competencies. As such, this study chose to adopt the TDCSI, which reflects these developments [19].

The present study first sought to evaluate the reliability and validity of the TDCSI and subsequently aimed to examine secondary school teachers' self-perceptions of their digital competence within the contemporary educational context.

**Figure 1**
**The construction of TDCSI**

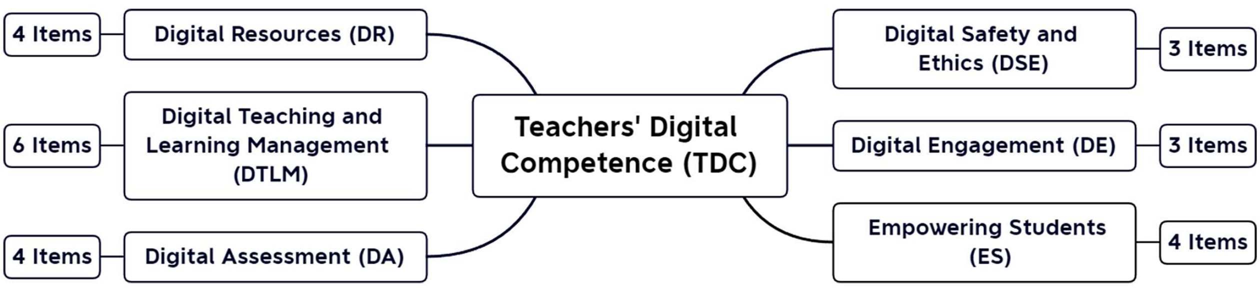

**Table 2**
**Statistics of several fit indices of the hypothetical model**

| Test | Fit index | Fit standard | Value | Result |
|---|---|---|---|---|
| Absolute Fit Index | GFI | > 0.8, indicating good model fit | 0.921 | Good |
| | RMSEA | < 0.06, indicating very good model fit | 0.055 | Good |
| | RMSR | < 0.05, indicating good model fit | 0.035 | Good |
| Incremental Fit Index | NFI | > 0.90, indicating good model fit | 0.898 | Acceptable |
| | CFI | > 0.90, indicating good model fit | 0.927 | Good |
| | IFI | > 0.90, indicating good model fit | 0.927 | Good |
| Parsimony Fit Index | x2/df | < 3, indicating good model fit | 2.31 | Good |
| | PCFI | > 0.50, indicating acceptable model | 0.793 | Acceptable |
| | PNFI | > 0.8, indicating good model fit | 0.768 | Acceptable |

### 3.3. Data analysis methods

All the data obtained for this study were analyzed using SPSS and AMOS version 26. SPSS includes various statistical methods, where descriptive statistical analysis can reveal teachers' digital competence levels, and analysis of variance can demonstrate differences in digital competence among teacher subgroups. For validity analysis, AMOS enables confirmatory factor analysis (CFA), assessing the questionnaire's structural validity by comparing model fit indices. In terms of reliability analysis, AMOS evaluates the reliability of individual dimensions and the overall questionnaire by calculating metrics such as composite reliability and Cronbach's alpha coefficient.

### 3.4. The reliability and validity of the questionnaire

To assess the reliability of the six dimensions and the overall scale, both Cronbach's $\alpha$ and Composite Reliability (CR) coefficients were employed to determine internal consistency. CFA was conducted using the diagonally weighted least squares estimation technique to evaluate the factorial validity of the scale.

Table 2 presents the results of the measurement model fit indices from the CFA. The indices indicate that the model exhibits a good fit for both the six dimensions and the overall scale. Specifically, the Root Mean Square Residual (RMSR) values were below 0.05, while the Incremental Fit Index (IFI), Goodness-of-Fit Index (GFI), Comparative Fit Index (CFI), and Relative Fit Index values exceeded 0.90. The Normed Fit Index (NFI) values were close to 0.90, demonstrating that the model fit for the six dimensions was satisfactory.

Table 3 reports that Cronbach's $\alpha$ values for all dimensions exceeded 0.8, indicating acceptable reliability of the instrument. Additionally, for convergent validity, the CR values were above 0.6, and the Average Variance Extracted (AVE) values were greater than 0.36 across all dimensions. Factor loadings were consistently above 0.50, further supporting the reliability and robustness of the model.

## 4. Results

To ensure the scientific rigor and validity of the data analysis, we initially performed a normality test on the sample data using histogram graphical methods. The results confirmed that the data followed a normal distribution. Subsequently, descriptive and inferential statistical techniques were utilized to analyze the sample data. The findings are detailed below.

**Table 3**
**Results of CFA, factor loadings, and reliabilities of the model**

| Dimension | Item | Factor loading | Cronbach's $\alpha$ | CR | AVE |
|---|---|---|---|---|---|
| Digital safety and ethics | 1 | 0.627 | 0.806 | 0.709 | 0.450 |
| | 2 | 0.725 | | | |
| | 3 | 0.656 | | | |
| Digital engagement | 4 | 0.708 | 0.865 | 0.699 | 0.439 |
| | 5 | 0.712 | | | |
| | 6 | 0.556 | | | |
| Empowering students | 7 | 0.657 | 0.859 | 0.763 | 0.447 |
| | 8 | 0.695 | | | |
| | 9 | 0.595 | | | |
| | 10 | 0.72 | | | |
| Digital resources | 11 | 0.623 | 0.874 | 0.783 | 0.475 |
| | 12 | 0.728 | | | |
| | 13 | 0.734 | | | |
| | 14 | 0.667 | | | |
| Digital teaching and learning management | 15 | 0.743 | 0.831 | 0.833 | 0.457 |
| | 16 | 0.782 | | | |
| | 17 | 0.644 | | | |
| | 18 | 0.667 | | | |
| | 19 | 0.574 | | | |
| | 20 | 0.625 | | | |
| Digital assessment | 21 | 0.657 | 0.832 | 0.837 | 0.563 |
| | 22 | 0.824 | | | |
| | 23 | 0.783 | | | |
| | 24 | 0.728 | | | |

### 4.1. Performance of individual items

We performed a statistical analysis of teachers' self-reported responses for each item. The TDCSI employs a five-point Likert scale, where responses range from "Strongly Disagree" to "Strongly Agree," with corresponding scores of 0, 1, 2, 3, and 4, respectively. Using these scores, we computed the mean and standard deviation for each item and presented the results in Figure 2.

Figure 2 illustrates that teachers' self-evaluations are relatively low for items DTLM2, DTLM5, DTLM6, and DA1. These items address critical areas of teaching, learning, and assessment, suggesting that teachers may exhibit weaknesses in areas such as promoting teaching innovation, supporting student self-directed learning, facilitating collaborative learning, and implementing digital assessment strategies. Conversely, higher mean scores were observed for items DE1, DE3, and DR1, suggesting that teachers demonstrate strong performance in digital professional development, the effective use

**Figure 2**
**Bar chart of means and standard deviations for each item**

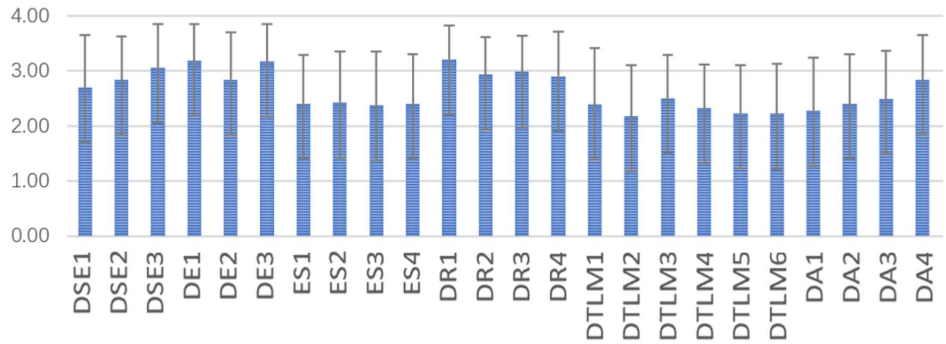


**Table 4**
**Conversion for TDCSI scores and proficiency levels**

| Score | 0~21 | 22~36 | 37~54 | 55~71 | 72~87 | 88~96 |
|---|---|---|---|---|---|---|
| Threshold ratio | | 0.227 | 0.386 | 0.568 | 0.750 | 0.920 |
| Level | A1 Newcomer | A2 Explorer | B1 Integrator | B2 Expert | C1 Leader | C2 Pioneer |

of digital resources, and communication and collaboration with students and parents.

## 4.2. Performance across dimensions and overall

The TDCSI consists of 24 items, with a maximum possible score of 96 points. In this study, we established new level thresholds by referencing the proportional relationship between score levels and categories defined in the DigCompEdu framework, as outlined in Table 4.

We conducted a statistical analysis of both the overall digital competence and the individual dimensions for the sample of teachers, with the results detailed in Table 5. To assess the proficiency level of each dimension, we compared the sum of the average item scores within each dimension to the total possible score for that dimension. This ratio was then used to determine the dimension's level based on predefined intervals.

Table 5 indicates that the sample's overall average score is 63.209, suggesting that the teachers' digital competence is generally moderate, corresponding to the B2 proficiency level. In terms of specific dimensions, teachers demonstrated C1-level competence in DR and DE, while the other four dimensions were at the B2 level. Analyzing the ratio of mean scores to the total scores reveals that teachers underperformed in the areas of empowering students and managing digital teaching and learning.

**Table 5**
**Statistical analysis of overall and dimensional digital competence levels in the sample**

| Dimension | Mean ± SD | Total | Mean/total | Level |
|---|---|---|---|---|
| DSE | 8.595 ± 1.896 | 12 | 0.716 | B2 |
| DE | 9.181 ± 1.752 | 12 | 0.765 | C1 |
| ES | 9.607 ± 2.81 | 16 | 0.600 | B2 |
| DR | 12.019 ± 2.151 | 16 | 0.751 | C1 |
| DTLM | 13.821 ± 3.917 | 24 | 0.576 | B2 |
| DA | 9.987 ± 2.902 | 16 | 0.624 | B2 |
| TDC | 63.209 ± 11.952 | 96 | 0.658 | B2 |

## 4.3. Differences in digital competence among teachers with different educational backgrounds

From Table 6, it is evident that there are significant statistical differences in self-perceived digital competence levels between teachers with graduate degrees and those with undergraduate degrees or lower (TDC, $p = 0.002 < 0.01$). Specifically, teachers holding master's or doctoral degrees demonstrate markedly higher digital competence compared to their counterparts with diplomas or bachelor's degrees. These differences are observed across various dimensions of digital competence.

Statistical differences in self-perceived competence are evident in the dimensions of digital safety and ethics, digital resources, and digital teaching and learning management, with $p$-values of less than 0.05. Additionally, in the dimension of digital engagement, significant statistical differences are noted between teachers with diplomas or bachelor's degrees and those with master's or doctoral degrees ($p = 0.015 < 0.01$). In the dimension of digital assessment, the differences are extremely significant ($p \leq 0.001$). Conversely, there are no statistically significant differences among teachers with varying educational backgrounds in the dimension of empowering students ($p > 0.05$).

## 4.4. Differences in digital competence among teachers based on teaching experience

Table 7 reveals an inverse relationship between teaching experience and self-perceived digital competence among teachers. Specifically, as teaching experience increases, the reported level of digital competence decreases. There is an extremely significant statistical difference in digital competence levels based on teaching experience (TDC, $p \leq 0.001$).

Regarding individual dimensions, teachers with less experience score higher in the areas of digital safety and ethics, digital engagement, digital resources, and digital assessment. Extremely significant statistical differences are found in digital competence across these four dimensions based on teaching experience ($p<0.001$). However, no statistical differences are observed

**Table 6**
**Results of the differences in digital competence among teachers with different educational backgrounds**

| | Mean ± SD | | | |
|---|---|---|---|---|
| Dimension | Diploma/Bachelor | Master/PH.D. | K-W | Sig. |
| DSE | 8.49 ±1.854 | 8.78 ±1.962 | –1.980 | 0.048* |
| DE | 9.05 ± 1.780 | 9.43 ± 1.672 | –2.950 | 0.003** |
| ES | 9.53 ± 2.737 | 9.75 ± 2.941 | –1.029 | 0.304 |
| DR | 11.88 ± 2.150 | 12.28 ± 2.133 | –2.439 | 0.015* |
| DTLM | 13.59 ± 3.882 | 14.25 ± 3.954 | –2.193 | 0.029* |
| DA | 9.70 ± 2.907 | 10.52 ± 2.820 | –3.724 | 0.000*** |
| TDC | 62.24 ± 11.906 | 65.02 ± 11.849 | –3.045 | 0.002** |

**Note:** *.Sig < 0.05; **.Sig < 0.01; ***.Sig < 0.001.

**Table 7**
**Results of the difference analysis of teacher digital competence based on teaching experience**

| | Years of teaching | | | | | | |
|---|---|---|---|---|---|---|---|
| Dimension | ~3 | 4~6 | 7~18 | 19~30 | 31~ | K-W | Sig. |
| | Mean ± SD | | | | | | |
| DSE | 9.161 ± 1.797 | 8.837 ± 1.835 | 8.516 ± 1.861 | 8.288 ± 1.921 | 8.063 ± 1.973 | 26.016 | 0.000*** |
| DE | 9.489 ± 1.657 | 9.081 ± 1.693 | 9.340 ± 1.711 | 8.891 ± 1.869 | 8.375 ± 1.563 | 22.162 | 0.000*** |
| ES | 9.905 ± 2.691 | 9.326 ± 2.793 | 9.447 ± 2.887 | 9.712 ± 2.694 | 9.979 ± 2.869 | 4.476 | 0.345 |
| DR | 12.613 ± 1.892 | 11.953 ± 1.855 | 12.006 ± 2.221 | 11.769 ± 2.233 | 11.333 ± 2.183 | 20.312 | 0.000*** |
| DT | 14.599 ± 3.750 | 13.512 ± 3.592 | 13.597 ± 4.019 | 13.673 ± 3.921 | 14.125 ± 3.898 | 9.316 | 0.054 |
| DA | 10.832 ± 2.513 | 10.419 ± 2.433 | 9.881 ± 3.051 | 9.301 ± 2.901 | 9.729 ± 2.970 | 24.812 | 0.000*** |
| TDC | 66.599 ± 10.393 | 63.128 ± 10.317 | 62.786 ± 12.239 | 61.635 ± 12.536 | 61.604 ± 12.943 | 17.713 | 0.001*** |

**Note:** *.Sig < 0.05; **.Sig < 0.01; ***.Sig < 0.001.

**Table 8**
**Results of the differences in teachers' digital competence across different regions**

| | Mean ± SD | | | | |
|---|---|---|---|---|---|
| Dimension | East | Center | West | K-W | Sig. |
| DSE | 8.963 ± 2.045 | 8.425 ± 1.652 | 8.392 ± 2.007 | 16.124 | 0.000*** |
| DE | 9.695 ± 1.675 | 8.887 ± 1.697 | 9.000 ± 1.787 | 33.808 | 0.000*** |
| ES | 9.931 ± 2.730 | 9.601 ± 2.712 | 9.177 ± 3.014 | 5.822 | 0.054 |
| DR | 12.638 ± 2.053 | 11.717 ± 2.074 | 11.707 ± 2.224 | 31.024 | 0.000*** |
| DT | 14.533 ± 4.022 | 13.852 ± 3.838 | 12.801 ± 3.671 | 18.753 | 0.000*** |
| DA | 10.654 ± 2.955 | 9.563 ± 2.822 | 9.823 ± 2.793 | 20.056 | 0.000*** |
| TDC | 66.415 ± 11.828 | 62.044 ± 11.649 | 60.901 ± 11.704 | 23.701 | 0.000*** |

**Note:** *.Sig < 0.05; **.Sig < 0.01; ***.Sig < 0.001.

in the dimensions of empowering students and digital teaching and learning management across varying levels of teaching experience ($p > 0.05$).

## 4.5. Differences in digital competence among teachers in various regions

Table 8 indicates that teachers in the eastern region report the highest levels of self-perceived digital competence, whereas those in the western region report the lowest. The statistical differences in self-perceived digital competence among teachers from the various areas are extremely significant (TDC, $p = 0.000$).

When examining specific dimensions of digital competence—namely, digital safety and ethics, digital engagement, digital resources, digital teaching and learning management, and digital assessment—there are significant statistical differences among teachers from the eastern, central, and western regions ($p = 0.000$). However, no statistical differences are observed among these regions in the dimension of empowering students ($p = 0.054 > 0.05$).

## 5. Conclusion and Discussion

### 5.1. The overall digital competence of Chinese secondary school teachers: strong but uneven across dimensions

Data analysis reveals that the overall digital competence of secondary school teachers in mainland China is relatively strong, with an average self-perception score of 63.209, which places it within the "moderate" range. This result aligns with findings for in-service mathematics teachers [20] and surpasses the competence levels observed in pre-service teachers [21].

In terms of specific competencies, Chinese secondary school teachers demonstrated their strongest performance in the domain of digital engagement, which may be attributed to China's well-established professional development system that supports teacher growth. However, the analysis also identified significant gaps in teachers' abilities to manage digital teaching and learning. Previous research by Lindberg et al. [22], based on small focus group interviews, indicated that teachers are acutely aware of the challenges posed by the digital era to their competence. A range of factors—including limited policy support, insufficiently targeted professional training, and a lack of adequate digital resources—contribute to this deficiency.

## 5.2. Distinct patterns of digital competence across teacher groups

There are notable patterns in the digital competence levels among teachers from different educational backgrounds. Specifically, teachers with postgraduate degrees (master's or higher) exhibit stronger digital competence compared to those with undergraduate degrees or below. This finding aligns with the research of Chen et al. [23], which reported that Chinese teachers with a master's or doctoral degree demonstrated higher overall information literacy. Similarly, Diz-Otero et al. [24] observed that "higher competence is seen in the use of digital content creation among faculty with master's degrees."

Our findings also indicate that younger teachers exhibit higher levels of self-perceived digital competence, consistent with the results of Nieto-Isidro et al. [25]. In contrast, older teachers [26] and those with more teaching experience [27] tend to report lower levels of self-assessed digital competence. One possible explanation for this discrepancy is that younger teachers are more likely to have been introduced to digital technologies earlier in their careers, which may lead to a more positive disposition toward these tools [28], as well as more frequent use of digital hardware and software.

## 5.3. Uneven development of digital competence among secondary school teachers across regions

Our research offers empirical evidence confirming the existence of a digital competence gap among teachers in mainland China. Previous studies have highlighted a significant decline in teachers' information literacy from the eastern to the central and western regions of China, with notable disparities across these areas [23]. In the western region, teachers encounter insufficient digital infrastructure and lower levels of information literacy [29]. In central China, while teachers acknowledge the importance of digital pedagogy, they have yet to fully integrate digital technologies into all phases of the instructional process [30]. In contrast, the eastern region, being the most economically advanced, exhibits higher levels of digital competence among teachers, who frequently incorporate information technology into their teaching practices [31].

The regional disparities in digital competence among secondary school teachers in China may stem from the economic prosperity of the eastern region, which ensures ample funding. This not only equips schools with advanced digital teaching facilities such as smart interactive whiteboards and virtual reality teaching equipment, establishes robust campus networks, but also offers teachers competitive salaries and abundant professional development opportunities, attracting highly educated talent proficient in cutting-edge digital technologies to the education sector. In contrast, the central and western regions face economic underdevelopment, strained educational budgets, inadequate teaching resources, and insufficient teacher compensation and career advancement prospects, all of which severely hinder the development of teachers' digital competence.

# 6. Recommendations and Strategies

Developing teachers' digital competence requires a systematic and sustained approach, involving coordinated efforts across educational, technological, and administrative sectors [32]. Additionally, it is essential to develop and effectively utilize high-quality educational resources. This includes integrating national education with public service platforms and support systems at various levels [33].

Enhancing teachers' digital competence also hinges on proactive innovation at the institutional level. Schools should evaluate their digital maturity to identify effective applications of digital resources and technologies within student management and student-centered instructional processes. Furthermore, schools should formulate personalized digital competence development plans tailored to the specific needs of each educator [34].

To address regions and schools with deficient levels of digital competence, it is crucial for local authorities to strategically coordinate educational resources. Priority should be given to resolving challenges related to digital equipment, resources, and faculty in these underserved areas. This includes enhancing the equitable distribution of digital infrastructure and resources, such as smart classrooms, digital learning platforms, and digital tools, to foster a digital educational environment.


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# Conflicts of Interest

The authors declare that they have no conflicts of interest to this work.

# Data Availability Statement

Data are available from the corresponding author upon reasonable request.

# Author Contribution Statement

**Lei Jiang:** Conceptualization, Methodology, Software, Validation, Formal analysis, Investigation, Writing – original draft, Writing – review & editing. **Na Yu:** Resources, Data curation, Visualization, Supervision, Project administration, Funding acquisition.

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