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Digital Competence of University Teachers in China: A Four-Dimensional Framework and Empirical Evidence

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Research Article

Keywords: Digital competence, University teachers, Higher education, China, Four-dimensional framework

Posted Date: November 27th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-11739970/v1

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Additional Declarations: No competing interests reported.

Abstract

Research on teacher digital competence has focused predominantly on K-12 populations, and the frameworks that guide this research, exemplified by DigCompEdu and national standards alike, center on pedagogical practice. University teachers' professional work spans teaching, research, and community engagement, yet how their digital competence varies across these domains, and which factors predict it, remains underexplored, particularly in the Chinese higher education context. Drawing on a four-dimensional framework encompassing digital teaching, digital research, digital social service, and digital professional development, this study examined the digital competence of 385 university teachers from across mainland China. A cross-sectional survey was conducted using a self-developed instrument. Data were analyzed with *t*-tests, ANOVAs, and hierarchical regression. Results indicated that digital teaching was the highest-scoring dimension and digital research the lowest. Age emerged as the most robust predictor across all dimensions, with the graded pattern suggesting a cohort effect. The effect of education level was dimension-dependent: doctoral degree holders scored significantly higher on digital research, an advantage that persisted after controlling for institutional characteristics. Gender differences were confined to digital research; academic rank showed no significant relationship; and no regional differences were observed. Degree-granting level was the most consistent institutional predictor. Individual and institutional factors operated through separate, non-interacting pathways. The findings demonstrate that expanding the conceptual scope of digital competence beyond pedagogical practice reveals meaningful variation across professional domains and calls for intervention strategies calibrated to specific dimensions and populations.

1 Introduction

In China, as elsewhere, university teachers today navigate a professional landscape shaped by the pervasive digital transformation of academic work. They design and deliver technology-enhanced courses, conduct research using computational tools and digital datasets, translate academic expertise for public audiences through online platforms, and continuously adapt to emerging technologies across all of these activities. This expanded scope of professional digital practice distinguishes university teachers from their counterparts in K-12 education, whose work centers more narrowly on classroom instruction. Yet the digital competence frameworks that shape educational policy and research, including China's recently issued Digital Literacy of Teachers (Ministry of Education of the People's Republic of China [MOE], 2022), were designed primarily for K-12 teachers and do not address the full range of professional demands that define academic careers.

Empirical research on teacher digital competence reflects this same imbalance. The majority of studies examine K-12 populations (Yang et al., 2023). A recent systematic review of Chinese university educators identified only 12 empirical studies, most limited to describing overall competence levels rather than systematically analyzing their determinants (Lan et al., 2024). Studies that do examine university teachers rarely assess digital competence across the breadth of academic professional work, including teaching, research, and community engagement, relying instead on frameworks built around pedagogical practice. Consequently, we know little about how university teachers' digital competence varies across different professional dimensions, which individual and institutional characteristics predict it, or whether these two sets of factors operate independently or in combination.

The present study addresses these gaps. Drawing on a four-dimensional framework that encompasses digital teaching, digital research, digital social service, and digital professional development, we examine the digital competence of 385 university teachers from across mainland China. Three research questions guide the analysis:

1. 1. What are the levels of digital competence among Chinese university teachers across the four dimensions?
2. 2. To what extent do individual characteristics (e.g., gender, age, education level) and institutional characteristics (e.g., institution type, degree-granting level) relate to digital competence?
3. 3. What are the relative contributions of individual and institutional factors, and do these two sets of factors interact?

2 Literature review

2.1 Digital competence: conceptual foundations

Digital competence has become a central construct in educational technology research, though its conceptual boundaries have been shaped by evolving and sometimes inconsistent terminology (Spante et al., 2018). In a foundational analysis commissioned by the European Commission, Ferrari (2012) defined digital competence as the confident, critical, and creative use of information and communication technologies to achieve goals related to work, learning, leisure, and participation in society. This definition marked a shift from earlier conceptions of "digital literacy" and "ICT skills," which tended to emphasize functional proficiency with specific tools. The conceptual evolution from skills to literacy to competence reflects a broader recognition that effective technology use in professional contexts requires not only technical proficiency but also critical judgment and contextual awareness. These conceptual differences are more than semantic: because each term foregrounds a different aspect of competence, the term a study adopts shapes how the construct is operationalized and measured.

For educators, professional digital competence extends beyond personal technology use to encompass the pedagogical, disciplinary, and institutional dimensions of technology integration (Instefjord & Munthe, 2017). This professional framing positions digital competence not as a fixed repertoire of technical abilities but as a capacity enacted within specific role contexts. The construct remains the same where frameworks adopt a different label: China's Digital Literacy of Teachers (MOE, 2022), for instance, uses “digital literacy,” yet refers to the same conceptual family.

While the conceptual foundations of digital competence were developed primarily in European scholarship, the construct has gained research traction in East Asian higher education contexts more recently. Zhao et al. (2021), in a comprehensive review of digital competence research in higher education, documented a growing but uneven body of scholarship, with the majority of studies originating from European contexts. Yang et al. (2023), in a systematic review of digital competence research on Chinese teachers, found that existing studies focused predominantly on K-12 populations, with higher education receiving considerably less attention. Their review further revealed that Chinese digital competence research has largely adopted frameworks developed in Western contexts, with limited attention to Asia-specific conceptualizations. This

uneven attention is reinforced by policy developments: China's Ministry of Education issued the Digital Literacy of Teachers (JY/T 0646–2022), signaling national-level recognition of the construct, yet the standard was designed primarily for K-12 teachers and does not address the distinctive demands of university-level professional work.

The institutionally situated conception of digital competence is particularly relevant in higher education. University teachers engage in a wider range of professional activities than their K-12 counterparts: classroom instruction, scholarly research, disciplinary knowledge production, community engagement, and continuous professional growth. Whether existing frameworks adequately capture this broader range of professional digital practice is the question to which we now turn.

2.2 Existing frameworks for teacher digital competence

To identify what established frameworks offer and where they fall short for capturing university teachers' digital competence, we review three influential frameworks selected for their breadth of adoption and policy influence. We examine them not as competing models but as complementary reference points, probing what each includes and what it leaves out.

The European Commission's **DigCompEdu** (Redecker, 2017) is among the most widely adopted educator-specific frameworks. It identifies six competency areas: professional engagement, digital resources, teaching and learning, assessment, empowering learners, and facilitating learners' digital competence, organized along six proficiency levels (A1–C2). It has been subjected to empirical validation (Ghomi & Redecker, 2019). However, DigCompEdu was designed primarily for K-12 educators. Its six areas center on pedagogical practice and learner support, with no dedicated attention to digital research competencies that are central to academic work in higher education.

In contrast to DigCompEdu's competency-area structure, **UNESCO's ICT Competency Framework for Teachers** (ICT-CFT), updated to its third version in 2018, adopts a curriculum integration perspective organized around three approaches to knowledge: acquisition, deepening, and creation (UNESCO, 2018). It has influenced teacher training programs globally, particularly in developing countries. Its emphasis on curriculum and pedagogy, however, means it does not address the range of professional activities that university teachers perform, which extend well beyond classroom instruction to include research and community engagement.

Among the three, **China's Digital Literacy of Teachers** (JY/T 0646–2022), issued in 2022, is distinctive for including "digital social responsibility" (ethical and civic dimensions of technology use absent from both DigCompEdu and UNESCO ICT-CFT) as an explicit competency domain. The standard defines digital competence across five dimensions: digital awareness, digital technology knowledge and skills, digital application, digital social responsibility, and professional development (MOE, 2022). However, like the other two frameworks, it was developed primarily for K-12 teachers and does not specifically address the integration of digital technologies into research and community engagement.

These frameworks share a structural limitation beyond omitting research domains. Each organizes competence around pedagogy and learner support, reflecting an implicit assumption that teaching

constitutes the core of teachers' work. This assumption, drawn from K-12 contexts where instruction is the primary mission, becomes problematic in higher education, where these three missions carry comparable institutional weight.

This pedagogical emphasis has consequences beyond the frameworks themselves. Professional development, institutional policy, and teacher education informed by these frameworks allocate resources predominantly around pedagogical digital competence, leaving research-related and service-related skills comparatively underdeveloped (Cabero-Almenara et al., 2021; Yang et al., 2023). The frameworks thus shape not only how digital competence is conceptualized but also how it is cultivated in practice.

Most recently, this conceptual landscape has been extended to address generative artificial intelligence. UNESCO's AI Competency Framework for Teachers (Miao & Cukurova, 2024) and DigComp 3.0 (Digital Competence Framework for Citizens; Cosgrove & Cachia, 2025) systematically integrate AI across competence areas but remain oriented predominantly toward K-12 contexts. The framework developed in this study predates these AI-specific extensions yet is positioned to incorporate AI-related items within each dimension, reflecting the multidimensional nature of university teachers' professional work in the AI era (Fan & Zhang, 2022).

Taken together, these frameworks offer an incomplete picture for university teachers, whose professional identities encompass teaching, research, and social service as equally weighted responsibilities. Moreover, although the HeDiCom framework (Higher Education teachers' Digital Competencies; Tondeur et al., 2023) targets higher education, it was developed in a European context and has not been validated in Asian higher education settings. A framework grounded in the institutional context of Chinese higher education, and one that captures all of university teachers' professional domains, is therefore needed.

2.3 Empirical evidence on factors associated with teacher digital competence

Beyond the conceptual and framework-level gaps identified above, empirical research has examined which individual and institutional characteristics are associated with teachers' digital competence, drawing predominantly on K-12 samples, though the evidence base remains fragmented and few studies examine the full set of relevant variables within a single analytic framework.

Age has been the most extensively studied individual predictor, though findings are mixed. Digital competence is often assumed to be higher among younger teachers, an assumption associated with the digital natives hypothesis (Prensky, 2001), which has since been widely contested. Empirical results are inconsistent: Suzer and Koc (2024) found digital competence to be independent of age among 368 Turkish teachers, and Cabero-Almenara et al. (2021) found age-related differences to vary by field of knowledge, suggesting the relationship may be context-dependent.

Gender differences have also been examined extensively, with similarly mixed results. Suzer and Koc (2024) found higher digital competence among male teachers in technically oriented dimensions, yet Instefjord and Munthe (2017) found no gender gap in the pedagogical dimensions among Norwegian pre-service teachers.

These inconsistencies suggest that gender differences, when present, may be dimension-specific rather than uniform.

Education level shows a more consistent pattern. Postgraduate degree holders score higher on digital competence (Suzer & Koc, 2024), with doctoral holders scoring highest in research-related dimensions (Wang & Chu, 2023). The mechanism remains unclear: it may reflect skills developed through advanced training, or institutional confounding, since doctoral holders concentrate in research-intensive universities.

Academic rank has received comparatively little attention. Chahuán-Jiménez et al. (2025) found no association between academic hierarchy and digital competence among 314 Chilean professors, and Xin et al. (2024) found that mid-level lecturers scored higher than both junior and senior-ranked teachers among 2,514 Chinese Technical and Vocational Education and Training (TVET) teachers. Digital competence does not appear to increase systematically with career advancement, raising questions about whether promotion criteria incentivize its development.

Discipline-level differences have been documented, with science and social science teachers tending to report higher digital competence than those in the humanities (Wang & Chu, 2023), though effect magnitudes vary across studies.

Institutional context has emerged as a significant factor, though research is less developed than on individual characteristics. Wang and Chu (2023) found that Chinese university teachers at "double world-class" institutions scored significantly higher than those at ordinary institutions, independent of individual characteristics. Institutional infrastructure, training opportunities, and policy support have been identified as recurring enabling conditions (Lan et al., 2024). The relative scarcity of institution-level evidence represents a notable gap.

Several limitations characterize the current literature. First, most studies examine K-12 populations, a focus reinforced by funding priorities that leave higher education digital competence comparatively under-resourced (Yang et al., 2023); only 12 empirical studies of Chinese university educators met inclusion criteria in a recent review, most describing competence levels rather than systematically analyzing determinants (Lan et al., 2024). Second, studies tend to examine individual and institutional factors in isolation rather than jointly modeling their relative contributions and interactions. Third, because most employ pedagogically focused frameworks, evidence on digital competence in non-teaching domains—particularly digital research and digital social service—is virtually absent. Fourth, most studies rely on cross-sectional, self-report designs with convenience samples, and heterogeneous instruments together with the infrequent reporting of reliability and validity evidence further limit comparability and generalizability, underscoring the need for validated, conceptually grounded measures.

These gaps motivate the present study. The evidence reviewed above suggests that age, education level, and institutional context are likely associated with university teachers' digital competence, while findings for gender, academic rank, and discipline are too mixed for directional predictions. Rather than advancing formal hypotheses, this study adopts a research-question approach, jointly examining individual and institutional predictors and their interactions within a multidimensional framework spanning the full scope of academic professional work.

3 Theoretical framework

3.1 A four-dimensional framework for university teacher digital competence

Drawing on the conceptual foundations and empirical gaps reviewed above, we propose a four-dimensional framework for university teacher digital competence: digital teaching, digital research, digital social service, and digital professional development.

The framework is grounded in the competence-theory tradition, in which competence is understood not as a generic trait but as a structured, context-dependent attribute that distinguishes effective from less effective performance within a specific role (McClelland, 1973; Spencer & Spencer, 1993). Two features of this tradition inform the framework's design. First, competence is layered: visible, trainable elements such as knowledge and skills are distinguished from less visible dispositions—self-concept, attitudes, and motives—as depicted in Spencer and Spencer's (1993) iceberg model and Boyatzis's (1982) onion model. Digital competence is therefore treated here as a unified capacity rather than a repertoire of technical skills alone. Second, competence is domain-specific: because it is defined against the demands of a particular role, the relevant competencies change as the role changes (McClelland, 1973), which implies that university teachers' digital competence should be specified function by function rather than collapsed into a single pedagogical capability.

The selection of these four dimensions is grounded in two considerations. The first is institutional. The tripartite mission of universities, comprising teaching, research, and social service, is formally codified in the Higher Education Law of the People's Republic of China (1998, amended 2018) and has been articulated internationally as the "third mission" of universities (Etzkowitz & Leydesdorff, 2000). Recent policy initiatives, notably China's "Double First-Class" construction program, have further elevated social service as an evaluation criterion for university performance, reinforcing the practical relevance of treating social service as a distinct digital competence domain. Digital professional development is included as a fourth, cross-cutting dimension, reflecting the widely recognized need for continuous learning amid rapidly evolving digital technologies (Instefjord & Munthe, 2017).

The second source is structural: the dimensional structure maps onto the four categories of professional activity that define academic work in Chinese higher education, ensuring that the framework captures the full scope of university teachers' digital practice rather than reducing it to pedagogical competence alone.

Digital teaching refers to the use of digital technologies to design, deliver, and assess learning experiences. This dimension aligns with the pedagogical competencies articulated in DigCompEdu (Redecker, 2017), reflecting broad agreement in the literature on the core components of digital teaching competence. We depart from DigCompEdu and similar frameworks, however, in one important respect: we position digital teaching as one of four co-equal domains rather than the organizing center of the framework. This reflects the reality of university teachers' work, where these three domains carry comparable institutional weight. It comprises three sub-dimensions: digital instructional design, digital teaching implementation, and digital teaching evaluation.

Digital research concerns the application of digital technologies to scholarly inquiry. Notably absent from all three frameworks reviewed above, this dimension captures what is arguably the most distinctive feature of university teachers' professional work: the production of disciplinary knowledge through research. As Weller (2011) argued, digital technologies have fundamentally transformed scholarly practice, creating new forms of knowledge production, peer review, and dissemination that require distinct competencies. Its three sub-dimensions are digital research problem identification, digital research problem solving, and digital research output sharing and collaboration.

Digital social service involves the use of digital platforms to translate academic expertise into practical applications for industry, community, and society. We use "social service" rather than "social responsibility"—the term in China's Digital Literacy of Teachers—because these concepts differ in scope. Social responsibility concerns the ethical and normative dimensions of technology use, such as digital safety, data privacy, and responsible online behavior. Social service refers to the outward-facing application of professional expertise, the "third mission" of universities (Etzkowitz & Leydesdorff, 2000), commonly termed community engagement in the wider literature. The dimension spans three sub-dimensions: digital transformation and application of research outputs, digital professional service and support, and digital social public welfare.

The fourth dimension, digital professional development, concerns the use of digital technologies for ongoing professional growth. This dimension resonates with DigCompEdu's "professional engagement" area and China's standard's "professional development" dimension (MOE, 2022), but we reconceptualize it specifically for academic career development in higher education. Unlike K-12 teachers, whose professional development is often structured around in-service training programs, university teachers navigate a more self-directed trajectory that spans teaching, research, and service activities. It is organized into four sub-dimensions: digital learning, reflection, and collegial engagement; digital teaching competence enhancement; digital research competence enhancement; and digital social service competence enhancement.

These four dimensions are not independent but structurally interrelated. Digital teaching, digital research, and digital social service share foundational digital skills (managing online platforms, curating digital content, communicating through digital channels) that transfer across domains. Digital social service draws on both teaching and research competencies, requiring scholars to translate specialized knowledge for diverse audiences. Digital professional development cuts across all three, sustaining currency in each.

3.2 Boundary conditions and contribution

We note two boundary conditions. First, the framework was developed in the context of Chinese higher education; its applicability to other national systems, while plausible given that the tripartite mission is widespread in many higher education systems, requires further validation. Second, the framework treats the four dimensions as equally relevant across all university types, but we acknowledge that the relative weight of research and social service may vary between research-intensive and teaching-oriented institutions. These boundary conditions do not undermine the framework's utility for the present study but delineate the scope within which its claims should be interpreted.

Conceptually, the framework makes two contributions to the literature. First, it extends prevailing conceptualizations of teacher digital competence beyond the pedagogical domain by formally incorporating

digital research and digital social service as independent dimensions, thereby aligning the construct more closely with university teachers' professional roles as a whole. Second, it demonstrates how the tripartite university mission translates into distinct digital competence dimensions, using Chinese higher education as an institutional case. It thus provides the conceptual architecture for the instrument and analytical approach described in the following section.

4 Method

4.1 Research design

This study employed a cross-sectional survey design to examine the digital competence of university teachers in China and to identify the individual and institutional factors associated with variation in competence levels. A nationwide questionnaire survey was conducted using a self-developed instrument grounded in the four-dimensional framework established in the preceding section. The cross-sectional design was appropriate for the study's dual objectives: to map the current state of university teachers' digital competence across multiple domains and to examine the relationships between competence levels and theoretically relevant factors. Two theoretical perspectives frame this examination: teacher career-development theory, which locates individual differences in the dynamics of professional growth across the career (Steffy & Wolfe, 2001), and organizational support theory, which attributes institutional differences to teachers' perceived support from their institutions (Eisenberger et al., 1986).

4.2 Participants and procedure

Simple random sampling was used to recruit university teachers from across mainland China. The questionnaire was completed online through the Wenjuanxing platform, a widely used online survey service in Chinese academic research. Data collection took place between October and November 2025.

A total of 528 questionnaires were returned. Each response was screened manually for quality: entries with implausibly short completion times, demonstrably inaccurate personal or institutional information, patterned response sets, or other indicators of random responding were excluded. After screening, 385 valid questionnaires were retained, yielding an effective response rate of 73%.

The questionnaire comprised two sections: a demographic and institutional information section and the digital competence scale described below. The demographic and institutional section comprised 11 items covering gender, age, education level, academic rank, discipline, institutional region, city tier, institution type, funding status, administrative affiliation, and degree-granting level. Female participants (55.8%) slightly outnumbered male participants (44.2%). Participants aged 45 and younger accounted for 69.1% of the sample, and those holding a master's or doctoral degree constituted 67.5%. By academic rank, mid-level and associate professors together represented 66.2% of respondents. The most heavily represented disciplines were engineering (29.6%), science (17.4%), and education (16.1%). In terms of institutional characteristics, public institutions comprised 84.4% of the sample, provincially administered universities accounted for 63.9%, and comprehensive universities constituted the largest institutional category (45.5%). Institutions in eastern China constituted the largest regional share (47.0%), followed by central (39.0%) and western (14.0%) regions.

The overall profile of the sample aligns with the national distribution of university teachers reported in China's annual education statistics, supporting the representativeness of the data.

4.3 Instrument

The instrument operationalizes digital competence as a self-rated construct, with respondents indicating their perceived capability to perform each professional task. This self-assessment approach is consistent with established digital competence instruments (Ghomi & Redecker, 2019) and reflects the enacted, role-specific nature of professional competence in higher education. The instrument was developed and administered in Chinese.

The instrument was developed through a two-phase process combining qualitative exploration with quantitative validation.

Phase 1: Indicator system development. Semi-structured interviews with 23 experts identified role-specific manifestations of digital competence in higher education. Responses were thematically coded and synthesized into an initial indicator system (four dimensions, 13 sub-dimensions, 25 indicators), which was refined through two rounds of Delphi consultation with 21 experts. The final consensus-based system retained the four-dimension framework.

Phase 2: Scale construction and validation. Scale items were written to operationalize each indicator (initial pool: 91 items). Nine experts reviewed the items for content validity, and the revised scale was administered in a pilot survey (n = 113).

Pilot data underwent item analysis; items with poor discrimination or corrected item-total correlations below .40 were removed. Factor analyses for each sub-dimension (DeVellis & Thorpe, 2021) confirmed a single-factor structure (Kaiser-Meyer-Olkin [KMO] and Bartlett's test satisfactory; variance explained: 55.6%–88.3%). Items with loadings below .45 were eliminated.

The overall scale demonstrated excellent internal consistency (α = .986), with sub-scale alphas ranging from .877 to .956 (Nunnally & Bernstein, 1994). Two additional items were removed to improve sub-scale reliability. The final instrument comprised 78 items across four dimensions: digital teaching (27 items), digital research (18 items), digital social service (18 items), and digital professional development (15 items). All items were rated on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree).

4.4 Data analysis

Data were analyzed in four stages. First, descriptive statistics (means and standard deviations) were computed for overall digital competence and each of the four dimension scores.

Second, independent-samples t-tests (binary variables, e.g., gender) and one-way ANOVA (variables with three or more categories) examined group differences. Significant ANOVAs were followed by Tukey's HSD or Tamhane's T2 post hoc comparisons depending on Levene's test, with partial η^2 as the effect size measure.

Third, two-way ANOVAs examined interactions between three factor pairs: education level × degree-granting level, age group × education level, and gender × education level. Non-significant interaction terms were

removed before interpreting main effects.

Fourth, hierarchical multiple regression assessed the relative contribution of individual and institutional factors. Individual characteristics (gender, age, education, academic rank, discipline) were entered in Block 1, and institutional characteristics (region, city tier, institution type, funding status, administrative affiliation, degree-granting level) in Block 2. Categorical predictors with uneven distributions were regrouped: age into three groups (26–35, 36–50, 51 and above); discipline into four categories (science/engineering; economics/education/management; agriculture/medicine; humanities/other: philosophy, law, literature, history, arts); institution type into five categories (comprehensive; normal/teachers; science/engineering/agriculture; medical; other: finance/economics, politics/law, language/foreign affairs, arts, sports, military/police, other); funding status into two categories (public; and all others); and administrative affiliation into three categories (ministry-affiliated; provincial; and all others). All were dummy-coded. Two cases from an under-represented discipline category were excluded (effective N = 383). Five models were estimated: one for overall digital competence and one for each dimension.

5 Results

5.1 Descriptive statistics of digital competence

Table 1 presents the means and standard deviations for overall digital competence and each of the four dimensions. The overall mean score was 3.78 on a five-point scale. Across the four dimensions, scores ranged from 3.62 to 3.88. Digital teaching received the highest mean score (M = 3.88), followed by digital professional development (M = 3.79), digital social service (M = 3.77), and digital research (M = 3.62).

Table 1
Descriptive Statistics for Overall and Dimension-Level Digital Competence (N = 385)

Variable	***M***	***SD***
Overall digital competence	3.78	0.71
Digital teaching	3.88	0.70
Digital research	3.62	0.86
Digital social service	3.77	0.76
Digital professional development	3.79	0.76

Note. All items rated on a five-point Likert scale (1 = strongly disagree, 5 = strongly agree).

5.2 Differences by individual characteristics

Table 2 presents the group comparisons across individual characteristics.

Age differences were significant across all five outcome variables. One-way ANOVAs yielded significant F values for overall digital competence, $F(7, 377) = 5.570$, $p < .001$, $\eta^2 = .094$; digital teaching, $F(7, 377) = 2.862$, $p = .007$, $\eta^2 = .050$; digital research, $F(7, 377) = 8.246$, $p < .001$, $\eta^2 = .133$; digital social service, $F(7, 377) = 5.219$, p

< .001, η^2 = .088; and digital professional development, $F(7, 377) = 4.656$, $p < .001$, η^2 = .080. Tukey HSD post hoc comparisons revealed a consistent pattern: the 51–55 age group scored significantly lower than younger age groups (26–50) on overall digital competence and all four dimensions. For digital social service, the 31–35 group also scored significantly higher than the 46–50 group.

Men and women did not differ on overall digital competence, digital teaching, digital social service, or digital professional development (all $p > .05$). However, men scored significantly higher on digital research ($M = 3.74$ vs. $M = 3.52$, $t = 2.451$, $p = .015$, $d = 0.25$).

Education level was associated with overall digital competence, $F(3, 381) = 3.059$, $p = .028$, η^2 = .024; digital research, $F(3, 381) = 4.934$, $p = .002$, η^2 = .037; and digital professional development, $F(3, 381) = 3.116$, p = .026, η^2 = .024. Post hoc comparisons showed that doctoral degree holders scored significantly higher than bachelor's degree holders on overall digital competence, and significantly higher than both bachelor's and master's degree holders on digital research.

Academic rank showed no significant differences on any dimension (F values ranged from 0.112 to 1.956, all $p > .05$). Discipline produced significant omnibus F values for overall digital competence, $F(12, 372) = 2.084$, p = .018; digital research, $F(12, 372) = 2.000$, $p = .024$; digital social service, $F(12, 372) = 2.426$, $p = .005$; and digital professional development, $F(12, 372) = 2.305$, $p = .008$. However, effect sizes were small-to-medium for all dimensions (η^2 = .06-.07), and post hoc comparisons identified only one consistent pairwise difference: economics scored significantly higher than engineering on digital research, digital social service, and digital professional development. Given the limited practical significance, discipline was retained in the subsequent regression analyses but was not emphasized as a major differentiating factor. For academic rank and discipline, only the omnibus F-statistic is reported; category-level means are omitted for brevity.

Table 2

Digital Competence by Individual Characteristics: Means, Group Comparisons, and Effect Sizes

Characteristic	Category	Overall	Digital teaching	Digital research	Digital social service	Digital professional development
Age						
	26–30	3.92	3.94	3.84	3.93	3.98
	31–35	3.99	4.04	3.92	4.01	3.96
	36–40	3.88	3.97	3.77	3.88	3.88
	41–45	3.74	3.85	3.54	3.74	3.76
	46–50	3.66	3.85	3.47	3.59	3.64
	51–55	3.21	3.44	2.79	3.23	3.25
	56–60	3.83	3.94	3.83	3.63	3.87
	61 and above	3.81	4.00	3.57	3.76	3.82
	$F(7, 377)$	5.570***	2.862**	8.246***	5.219***	4.656***
	η^2	.094	.050	.133	.088	.080
Gender						
	Male	3.84	3.93	3.74	3.83	3.84
	Female	3.72	3.84	3.52	3.72	3.75
	$t(383)$	1.687	1.219	2.451*	1.451	1.105
	d	—	—	0.25	—	—
Education level						
	Associate	3.79	3.82	3.72	3.77	3.87
	Bachelor's	3.67	3.80	3.48	3.66	3.66
	Master's	3.71	3.84	3.48	3.72	3.72
	Doctoral	3.93	4.01	3.84	3.88	3.94
	$F(3, 381)$	3.059*	2.091	4.934**	1.600	3.116*
	η^2	.024	—	.037	—	.024
Academic rank						
	$F(3, 381)$	0.741	0.112	1.956	0.894	0.814
Discipline						

Characteristic	Category	Overall	Digital teaching	Digital research	Digital social service	Digital professional development
	F(12, 372)	2.084*	1.463	2.000*	2.426**	2.305**
	η²	.063	—	.061	.073	.069

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. Effect sizes (Cohen's *d* or η²) are reported for significant effects. Dash (—) indicates the effect was non-significant and effect size is not reported. The military science category ($n = 2$) was retained in the ANOVA for completeness; its means should be interpreted with caution. Category-level means for academic rank and discipline are omitted for brevity; only omnibus *F*-statistics are reported.

5.3 Differences by institutional characteristics

Table 3 presents digital competence means and ANOVA results across institutional characteristics.

Geographic region yielded no significant differences on any dimension (all $F < 0.51$, all $p > .05$). City tier was significantly associated only with digital teaching, $F(3, 381) = 2.927$, $p = .034$, $\eta^2 = .023$. Tukey HSD post hoc comparisons indicated that teachers in municipalities scored higher than those in provincial capitals ($p = .035$) and prefecture-level cities ($p = .047$).

Institution type showed no significant differences on any dimension (all $F < 1.65$, all $p > .05$). Funding status similarly showed no significant differences (all $F < 2.56$, all $p > .05$). Administrative affiliation reached significance across all five outcome variables: overall digital competence, $F(5, 379) = 2.869$, $p = .015$; digital teaching, $F(5, 379) = 2.346$, $p = .041$; digital research, $F(5, 379) = 2.846$, $p = .016$; digital social service, $F(5, 379) = 3.130$, $p = .009$; and digital professional development, $F(5, 379) = 2.396$, $p = .037$. Tukey HSD post hoc comparisons showed that teachers from ministry-affiliated universities scored significantly higher than those from provincially administered and sub-provincially administered institutions on four of the five outcome variables (overall, digital teaching, digital research, and digital social service); no significant pairwise differences emerged for digital professional development. For institution type and funding status, only the omnibus *F*-statistic is reported; category-level means are omitted for brevity.

Degree-granting level produced the most pronounced institutional differences. ANOVAs were significant for all five outcome variables: overall digital competence, $F(3, 381) = 7.534$, $p < .001$, $\eta^2 = .056$; digital teaching, $F(3, 381) = 8.107$, $p < .001$, $\eta^2 = .060$; digital research, $F(3, 381) = 6.685$, $p < .001$, $\eta^2 = .050$; digital social service, $F(3, 381) = 4.509$, $p = .004$, $\eta^2 = .034$; and digital professional development, $F(3, 381) = 6.615$, $p < .001$, $\eta^2 = .050$. Tukey HSD post hoc comparisons showed a consistent pattern: teachers from doctoral-degree-granting universities scored significantly higher than those from bachelor-degree-granting universities and vocational colleges on all five outcome variables. No significant differences emerged between doctoral-granting and master's-granting institutions.

Table 3

Digital Competence by Institutional Characteristics: Means, Group Comparisons, and Effect Sizes

Characteristic	Category	Overall	Digital teaching	Digital research	Digital social service	Digital professional development
Region						
	Eastern	3.80	3.91	3.63	3.80	3.81
	Central	3.74	3.84	3.60	3.73	3.76
	Western	3.78	3.91	3.60	3.75	3.80
	F(2, 382)	0.297	0.505	0.069	0.405	0.207
City tier						
	Municipality	4.00	4.17	3.83	3.92	3.97
	Provincial capital	3.73	3.82	3.56	3.74	3.79
	Prefecture-level city	3.76	3.87	3.61	3.76	3.77
	County-level city	3.70	3.79	3.59	3.70	3.69
	F(3, 381)	1.621	2.927*	1.064	0.736	1.020
	η^2	—	.023	—	—	—
Institution type						
	F(11, 373)	1.163	1.229	0.861	1.030	1.646
Funding status						
	F(3, 381)	1.575	2.265	0.568	2.551	1.826
Administrative affiliation						
	Ministry-affiliated	4.15	4.18	4.07	4.18	4.13
	Province-affiliated	3.77	3.89	3.60	3.75	3.78
	Sub-province/municipal	3.65	3.74	3.42	3.71	3.68
	Social organization/foundation	3.44	3.62	3.43	3.30	3.30
	Enterprise/individual	3.67	3.70	3.60	3.66	3.72
	Other	3.72	3.80	3.66	3.65	3.76
	F(5, 379)	2.869*	2.346*	2.846*	3.130**	2.396*
	η^2	.036	.030	.036	.040	.031

Characteristic	Category	Overall	Digital teaching	Digital research	Digital social service	Digital professional development
Degree-granting level						
	Doctoral	3.96	4.08	3.82	3.92	3.98
	Master's	3.78	3.87	3.65	3.77	3.79
	Bachelor's only	3.52	3.66	3.30	3.55	3.51
	Vocational	3.59	3.67	3.42	3.62	3.64
	F(3, 381)	7.534***	8.107***	6.685***	4.509**	6.615***
	η²	.056	.060	.050	.034	.050

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. Effect sizes (η²) are reported for significant omnibus effects. Dash (—) indicates the omnibus *F* was non-significant and effect size is not reported. Category-level means for institution type and funding status are omitted for brevity; only omnibus *F*-statistics are reported.

5.4 Two-way ANOVA: interaction effects

Two-way ANOVAs examined three factor pairs: education level × degree-granting level, age group × education level, and gender × education level. For these analyses, age was recoded into three groups (26–35, 36–50, and 51 and above). Each pair was tested on overall digital competence and the four dimensions, yielding 15 tests.

Across all 15 tests, no interaction effect reached statistical significance (Table 4). The interaction terms were therefore removed, and main effects were examined.

For education × degree-granting level, the degree-granting level main effect was significant across all five outcome variables (all $p < .05$, partial $\eta^2 = .029$-$.051$), while the education main effect reached significance only for digital research ($p = .010$, partial $\eta^2 = .030$).

For age × education, the age main effect was significant across all five outcome variables (all $p < .01$, partial $\eta^2 = .029$-$.093$), with digital research showing the largest age effect (partial $\eta^2 = .093$). Post hoc comparisons showed a graded pattern: the 26–35 group scored significantly higher than the 36–50 group, who in turn scored significantly higher than the 51-and-above group on overall digital competence, digital research, digital social service, and digital professional development. The education main effect was significant for overall digital competence ($p = .040$), digital research ($p = .003$), and digital professional development ($p = .031$), with doctoral degree holders scoring higher than bachelor's or master's degree holders.

For gender × education, the gender main effect was significant only for digital research ($p = .038$, partial $\eta^2 = .011$), with men scoring higher than women. The education main effect was significant for overall digital competence ($p = .045$), digital research ($p = .005$), and digital professional development ($p = .034$).

Table 4

Two-Way ANOVA Results: Interaction p-Values and Main Effect Partial η²

Factor pair	Effect	Overall	Digital teaching	Digital research	Digital social service	Digital professional development
Education × Degree-granting level	Interaction *p*	.948	.701	.958	.806	.997
	Education partial η²	.015	.007	.030	.007	.018
	Degree-granting partial η²	.048	.051	.042	.029	.043
Age × Education	Interaction *p*	.164	.167	.151	.170	.121
	Age partial η²	.064	.029	.093	.064	.056
	Education partial η²	.022	.014	.037	.011	.023
Gender × Education	Interaction *p*	.799	.756	.594	.871	.720
	Gender partial η²	.005	.002	.011	.004	.002
	Education partial η²	.021	.014	.033	.011	.023

Note. All interaction terms were non-significant (all $p > .05$). Interaction terms were removed before examining main effects. Partial η² values are reported for main effects from models without interaction terms. For each factor pair, separate two-way ANOVAs were conducted on each of the five outcome variables.

5.5 Hierarchical regression analysis

Table 5 presents model summaries and key coefficients for the five hierarchical regression models. Individual characteristics were entered in Block 1 and institutional characteristics in Block 2. The effective sample for all regression analyses was 383.

Table 5

Hierarchical Regression Results: Model Summaries and Key Standardized Coefficients Panel A: Model Summaries

Statistic	Overall	Digital teaching	Digital research	Digital social service	Digital professional development
Block 1 R^2	.118	.071	.165	.111	.108
Block 1 $F(12, 370)$	4.138***	2.365**	6.072***	3.832***	3.726***
Block 2 R^2	.198	.170	.232	.169	.176
ΔR^2	.080	.098	.068	.058	.068
$\Delta F(15, 355)$	2.356**	2.800***	2.086*	1.655	1.959*

Panel B: Key Standardized Coefficients (Block 2)

Predictor (reference group)	Overall β	Digital teaching β	Digital research β	Digital social service β	Digital professional development β
Age 36–50 (vs. 26–35)	− .110	− .037	− .129*	− .144*	− .122
Age 51 and above (vs. 26–35)	− .243***	− .156*	− .287***	− .260***	− .221***
Gender male (vs. female)	.071	.037	.112*	.068	.047
Education doctoral (vs. master's)	.103	.081	.155**	.050	.093
Discipline: economics/education/management (vs. science/engineering)	—	—	—	.122*	—
Discipline: agriculture/medicine (vs. science/engineering)	—	− .123*	—	—	—
Degree-granting: doctoral (vs. master's)	.180**	.209**	.132*	.135*	.183**
Degree-granting: bachelor's only (vs. master's)	− .109	− .094	− .122*	− .077	− .116
Degree-granting: vocational (vs. master's)	− .132	− .132	− .143*	− .100	− .110
City: provincial capital (vs. prefecture-level)	—	—	− .116*	—	—
Institution type: teachers' college (vs. comprehensive)	—	.110*	—	—	—

Note. * $p < .05$, ** $p < .01$, *** $p < .001$. Dash (—) indicates the predictor was non-significant in that model. Only predictors reaching significance in at least one Block 2 model are displayed. Block 1 included gender, age, education, academic rank, and discipline; Block 2 added region, city tier, institution type, funding status,

administrative affiliation, and degree-granting level. Age was recoded into three groups; categorical predictors were dummy-coded. Effective $N = 383$.

Block 1 (individual characteristics) accounted for 11.8% of the variance in overall digital competence, $F(12, 370) = 4.138$, $p < .001$. The variance explained by Block 1 ranged from 7.1% (digital teaching) to 16.5% (digital research) across the five outcome variables. Block 2 contributed significant additional variance for four of the five outcome variables ($\Delta R^2 = .068$ to .098, all ΔF $p < .05$), with the largest increment for digital teaching ($\Delta R^2 = .098$, ΔF $p < .001$). For digital social service, the institutional block did not significantly improve the model ($\Delta R^2 = .058$, $\Delta F = 1.655$, $p > .05$). The full models explained 16.9% to 23.2% of the total variance.

Age was the only predictor significant across all five models in both blocks. The 51-and-above age group showed consistently negative and significant standardized coefficients in both Block 1 and Block 2 for all five outcome variables (Block 2 β ranged from − .156 to − .287, all $p < .05$). The 36–50 age group showed significant negative coefficients for digital research (β = − .129, $p = .035$) and digital social service (β = − .144, $p = .024$) in Block 2.

Gender was a significant predictor only for digital research, with men scoring higher than women in both Block 1 (β = .120, $p = .014$) and Block 2 (β = .112, $p = .021$). This effect was not significant for any other dimension.

The doctoral degree effect revealed a notable pattern. In Block 1, doctoral degree (vs. master's) was a significant positive predictor of overall digital competence, digital teaching, digital research, and digital professional development (β = .128 to .197, all $p < .05$). After institutional characteristics were entered in Block 2, the doctoral advantage became non-significant for overall digital competence (β = .103, $p = .085$), digital teaching (β = .081, $p = .183$), and digital professional development (β = .093, $p = .123$). For digital research, however, it remained significant (β = .155, $p = .008$).

Academic rank showed no significant coefficients across any model in either block (all $p > .05$), confirming the ANOVA results.

Among institutional predictors, degree-granting level was the most consistent. Doctoral-degree-granting status (vs. master's-granting) was a significant positive predictor across all five outcome variables (β = .132 to .209, all $p < .05$). Bachelor-degree-granting and vocational statuses showed significant negative coefficients for digital research (β = − .122, $p = .036$ and β = − .143, $p = .037$).

Other institutional variables showed limited effects. City tier reached significance for digital research, with provincial-capital locations scoring lower than prefecture-level cities (β = − .116, $p = .039$). Institution type (teachers' college) was a significant positive predictor for digital teaching only (β = .110, $p = .044$). Administrative affiliation, region, and funding status did not reach significance in any full model.

6 Discussion

This study examined the digital competence of Chinese university teachers across four dimensions: digital teaching, digital research, digital social service, and digital professional development. The most consistent

pattern was that competence varied systematically by dimension and by age, with digital teaching scoring highest, digital research lowest, and age the strongest individual predictor across all dimensions. Institutional differences were concentrated at the degree-granting level, and individual and institutional factors operated largely independently.

6.1 Patterns of digital competence among university teachers

The finding that digital teaching received the highest mean score is consistent with the emphasis that existing frameworks place on pedagogical practice. DigCompEdu (Redecker, 2017), UNESCO ICT-CFT (UNESCO, 2018), and China's Digital Literacy of Teachers (MOE, 2022) all center on teaching-related competencies. This shared orientation has shaped where institutional resources and professional development efforts are directed. University teachers, whose professional responsibilities extend beyond those of K-12 counterparts, appear strongest in the domain that receives the most systemic support.

The substantially lower score for digital research (M = 3.62 vs. M = 3.88 for teaching) warrants attention. Yang et al. (2023), in their systematic review, noted that existing studies have focused predominantly on K-12 populations and teaching contexts. The present findings suggest this pedagogical emphasis has a counterpart in practice: university teachers are considerably less prepared to integrate digital technologies into their scholarly work, likely because research-specific competencies fall outside prevailing frameworks and the professional development programs built upon them.

Counterintuitively, no regional differences in digital competence emerged, despite economic disparities between eastern, central, and western China. This indicates that sustained investment in educational technology infrastructure and widespread digital access in higher education may have narrowed regional gaps at the university level.

6.2 Individual-level predictors: age, education, and gender

Age emerged as the dominant predictor, with significant effects across all five outcome variables in both blocks. The 51-and-above age group showed consistently negative coefficients (Block 2 β = − .156 to − .287, all p < .05), and the 51–55 group scored below all younger groups in one-way ANOVAs. The age effect follows a graded pattern across the recoded age groups (26–35 > 36–50 > 51 and above), with the lowest scores concentrated among teachers in their early fifties. Taken together, these results suggest a cohort effect rather than the binary "digital natives" versus "digital immigrants" division (Prensky, 2001). Teachers entering the profession more recently likely encountered digital technologies earlier and benefited from their integration into graduate education and early-career professional development.

The doctoral degree effect revealed a dimension-specific pattern. In Block 1, doctoral degree holders scored significantly higher than master's holders on overall digital competence, digital teaching, digital research, and digital professional development. After Block 2 (institutional characteristics), the doctoral advantage became non-significant for most dimensions but persisted for digital research (β = .155, p = .008). This attenuation likely reflects the institutional concentration of doctoral holders (50.4% worked in doctoral-granting universities), where richer digital infrastructure elevates competence across multiple domains. The

persistence of the digital research effect underscores the value of maintaining this dimension as distinct in the framework.

Gender differences were limited to digital research, where men scored higher than women in both the one-way ANOVA (d = 0.25) and the hierarchical regression (Block 2 β = .112, p = .021). The absence of gender differences in digital teaching, digital social service, and digital professional development is noteworthy: it suggests that the gender gap in technology-related competence among university teachers may be narrower than often assumed. The concentration of the gap in digital research, however, is consistent with broader patterns in academic work, where gender disparities in research productivity and research-related resources have been observed across multiple national contexts. The finding that digital teaching shows no gender gap may reflect the normalization of educational technology use in classroom settings across genders, a pattern also observed by Instefjord and Munthe (2017) in their study of Norwegian teacher education.

Academic rank showed no significant relationship with digital competence in either the one-way ANOVAs or the hierarchical regression. This null finding is informative: it indicates that digital competence does not systematically increase with career advancement, at least as measured by the conventional academic rank hierarchy. One interpretation is that academic promotion criteria in Chinese universities have historically prioritized research publications and project funding over teaching innovation and technology integration; although recent policy reforms have sought to broaden evaluation criteria (State Council of the People's Republic of China, 2020), digital competence has yet to be explicitly incorporated into most institutional promotion frameworks. If digital competence is to be cultivated across the academic career span, institutional incentives may need to be realigned.

6.3 The role of institutional context

Institutional characteristics contributed modest but non-trivial additional variance in digital competence beyond individual factors (ΔR^2 = .058 to .098). Degree-granting level was the most consistent institutional predictor, with teachers from doctoral-degree-granting universities scoring significantly higher than those from bachelor-degree-granting universities and vocational colleges on all five outcome variables. This gradient likely reflects differences in institutional resources, research intensity, and the professional expectations placed on faculty. Doctoral-granting universities in China tend to have greater access to research funding, more extensive digital infrastructure, and stronger international scholarly connections, conditions that may collectively foster higher levels of digital competence among their faculty.

Notably, digital social service was the only dimension for which the institutional block did not significantly improve model fit (ΔR^2 = .058, ΔF = 1.655, p > .05). This implies that digital social service depends more on individual motivation, professional values, and personal networks than on institutional context. The finding resonates with the characterization of social service as the "third mission" of universities (Etzkowitz & Leydesdorff, 2000), an endeavor that has historically been driven by individual faculty initiative rather than institutional mandate. The non-significance of geographic region across all five dimensions and the non-significance of administrative affiliation in the full regression models further suggest that within Chinese higher education, institutional stratification by degree-granting level is a more powerful differentiator of digital competence than either geographic location or administrative hierarchy.

The absence of significant interaction effects across all 15 two-way ANOVA tests carries an important implication: individual and institutional factors influence digital competence independently. Higher education level does not compensate for age-related differences in digital competence, nor does working in a doctoral-granting university close the gender gap in digital research. The factors identified in this study appear to operate through separate pathways, which means that interventions targeting one source of variation—such as professional development for mid-career and senior teachers—cannot be expected to address gaps arising from other sources, such as institutional resource disparities.

6.4 Limitations and implications

Several limitations warrant consideration. The cross-sectional design precludes causal inference; longitudinal research is needed. All measures were self-reported, introducing potential social desirability bias and common method variance; future research employing performance-based measures would strengthen the evidence base. The sample, while geographically diverse, may be subject to non-response bias; replication with alternative sampling frames would strengthen generalizability. The four-dimensional framework was developed and tested in the Chinese higher education context; applicability to other national systems requires empirical verification, and future research could extend it by integrating AI-specific competencies from frameworks such as UNESCO's AI Competency Framework for Teachers (Miao & Cukurova, 2024) and DigComp 3.0 (Cosgrove & Cachia, 2025).

In practical terms, the findings point to several priorities. Professional development programs targeting digital research competence are needed, given that this dimension scored lowest across the sample. Special attention should be directed toward teachers in the 51-and-above age group, whose digital competence scores were systematically lower, and toward teachers in bachelor-degree-granting universities and vocational colleges, whose institutional environments appear to provide fewer opportunities for digital competence development. The finding that academic rank is unrelated to digital competence suggests that institutional incentive structures, including promotion criteria, may need revision to recognize and reward the development of professional digital competence.

7 Conclusion

The most consequential finding extends beyond which dimension scored highest or lowest: a framework spanning the full scope of academic professional work reveals variation that would remain invisible under pedagogically focused models. Digital teaching, the dimension best covered by existing frameworks, was the highest-scoring dimension. Digital research, a dimension absent from each of these prevailing models, was the lowest-scoring. This symmetry between conceptual coverage and observed competence levels suggests that the scope of prevailing frameworks has directed resources toward pedagogical digital skills, leaving research-specific competencies systematically neglected. The independent-pathways finding reinforces this interpretation: factors that produce variation do not compensate for one another, so closing gaps in one dimension will not automatically close gaps in others.

Empirically, the study makes three contributions. First, it validates a four-dimensional digital competence framework extending beyond the pedagogical focus of existing models to encompass digital research, digital social service, and digital professional development as equally weighted domains, addressing a structural gap

identified by Tondeur et al. (2023). Second, by demonstrating that individual and institutional factors operate independently, the study provides an evidence base for differentiated intervention strategies. Third, the finding of no regional differences offers a counterpoint to deficit narratives about digital readiness in less developed regions of China.

National standards, including China's Digital Literacy of Teachers, would benefit from encompassing all academic professional activities, particularly digital research. Because individual and institutional sources of variation operate independently, professional development and institutional investment cannot substitute for one another; improving infrastructure alone is unlikely to close age-related gaps. The four-dimensional model offers a starting point for the comparative work needed to test its generalizability beyond Chinese higher education.

Declarations

Author Contribution

G.W. and X.L. contributed to the conceptualization and methodology of the study. G.W. was responsible for investigation, formal analysis, and data curation, and wrote the original draft of the manuscript. X.L. supervised the study and revised and edited the manuscript. All authors reviewed and approved the final manuscript.

Acknowledgement

The authors thank the 23 experts who participated in the semi-structured interviews, the 21 experts who served on the two rounds of the Delphi consultation, and the 9 experts who reviewed the draft items for content validity. The authors also thank the university teachers who participated in the survey for their time and responses.

Data Availability

The datasets generated and analyzed during the current study are not publicly available due to the confidentiality assured to participants but are available from the corresponding author on reasonable request.

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