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Promoting Lifelong Learning and Enhancing Teachers' Digital Competence in Chinese Higher Education

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Abstract

In the knowledge economy of the 21st century, the digital competence of higher education faculty has a clear impact on teaching quality; however, the underlying structure of faculty competence remains poorly understood, particularly in a regional context. This study explored

the fundamental dimensions of faculty competence in Zhejiang Province, China, with the goal of developing a valid, data-based framework to inform institutional policy and professional support. A quantitative survey of 84 educators from universities was conducted, including four fundamental modules of competence: digital competence, technical competence, school climate, and professional advancement. Principal component analysis (PCA) and Cronbach's alpha tests revealed that two hidden components explained 42.95% of the total variance. Integrated Digital Pedagogical Competence (IDPC) and Collaborative Professional Ecology (CPE) both demonstrated high levels of internal consistency, with α = .965 for the former and α = .949 for the latter. The results present a two-dimensional framework in which four fundamental modules combine to systematically integrate teachers' digital-pedagogical skills and factors that support them at work and in school. This framework provides both an argument and an approach toward enhancing faculty digital literacy, pedagogical innovation, and lifelong learning in higher education in China.

Keywords：Digital Competency Skills, Higher Education Faculty, Principal Component Analysis (PCA), Professional Development

1. Introduction

In the era of future-oriented learning in the 21st-century knowledge economy, lifelong learning has changed from a prospective concept to an unavoidable pressure to maintain employment amidst highly uncertain careers and rapidly changing higher education, thus becoming a necessity. Digital technology is the major driving force of change in education. Its fast and continuous innovation changes the way of teaching by teachers, encourages more people to learn online, and has a direct impact on the quality of teaching in general (Zhang & Wu, 2025). Digital tools have shifted from being additional instruments to being basic elements of modern teaching (Nassor et al., 2026). This digital change itself reveals the importance of digital literacy. Reports from UNESCO and other international organizations state that digital literacy is an important skill that anyone in society, especially teachers, needs to have. It is also important to develop evidence-based digital literacy courses for students (Buchan et al., 2024; Govender, 2025).

College instructors are the key figures for this change by promoting the integration and application of digital technology in the teaching environment. Professional digital competence is a complex and comprehensive idea that transcends digital skills (Zhao et al., 2021). A recent empirical study in China’s higher education proves that this competency involves not only digital skills but also the application of digital tools in pedagogy (Feng & Sumittikon, 2024). To be professionally digital, teachers must be able to use technology in lessons and have general skills that work in a wide variety of teaching situations. Digital proficiency is explicitly recognized as an important part of teacher education and professional development worldwide, highlighting the key role of teacher education efforts in this process (Norhagen et al., 2024; Desniyanti, 2025; Asterhan & Lefstein, 2024).

While digital literacy is generally perceived as important, there is often a big gap between what college teachers expect from their students and what colleges and universities do in helping them to fill that gap. Most teachers find it difficult to use digital technology in the classroom

and their real-world experience shows their incompetence and lack of knowledge in using digital tools. This disconnect can easily lead to the collapse of training programs, making teachers even more nervous about new technologies and diminishing the impact of digital tools on lifelong learning.

This issue has been documented in a number of previous studies and major international reports. The Organization for Economic Cooperation and Development (OECD) pointed out that although technical equipment is usually available, most teachers do not often use digital tools in classroom teaching, which reflects the systematic disconnect between policy expectations and actual teaching practices (OECD, 2019b, 2020, 2021). In response to this problem, the academic community began to discuss the necessity of establishing reliable assessment methods and measurement tools, which is reflected in the comprehensive study of multiple assessment frameworks (Nguyen & Habók, 2024).

While this universal problem and assessment needs have been fully recognized, relevant discussions remain mostly at the macro level. There is a lack of empirical research beyond these general conclusions that can accurately identify and define the specific core elements and systemic influencing factors of digital skills in localized and demanding regional situations. This is especially prominent in Zhejiang Province, where despite being at the forefront of China's economic and scientific and technological development, its high-level educational competitive environment highlights the need for in-depth research on the digital ability of university teachers.

To address this specific research gap, the present study aims to accurately identify and define the core components of digital skills among teachers in colleges and universities across Zhejiang Province and their systemic influencing factors. The findings hope to provide an empirical basis for the formulation of targeted interventions, aiming to help the region maintain a competitive advantage in the field of education and effectively promote the lifelong learning culture of college teachers. To realize these aspirations, this study is guided by the following research questions:

RQ1：What is the current scenario of college teachers in Zhejiang Province regarding personal digital literacy and college support environment?

RQ2：Based on the findings of the principal component analysis, which components best represent these two dimensions?

RQ3：Based on the acknowledged component structure, what practical advice can be given to boost the digital literacy of college teachers and strengthen the lifelong learning culture?

The significance of this study is reflected in two aspects. At the theoretical level, it investigated, built, and verified a local digital ability model of college teachers, hence enriching the foundation of academic literature that often overlooks China’s higher education landscape. The framework provides a more detailed perspective for analyzing the specific skill elements and environmental factors shaping the ability of educators in the digital age. At the practical level, the findings provide diagnostic tools for colleges and universities to conduct institutional self-assessment and lay an empirical foundation for the design of targeted and efficient

professional development projects for teachers. Finally, it offers a theoretical and practical basis for colleges and universities to formulate strategies that can systematically improve teachers' digital ability and cultivate a sustainable lifelong learning culture.

2. Literature Review

2.1 Research on the Framework of What Constitutes Digital Competency for Teachers

In recent years, the need for digital transformation in education has prompted many countries and regions to commit to the systematic construction of teachers' digital capacity frameworks. This is particularly true in the context of China's higher education, where urgent calls have been made on the need to conduct empirical analysis of such frameworks and promote their systematic construction (Feng & Sumittikon, 2024). In response to the issue, the Ministry of Education of China established the "Teachers' Digital Literacy" industry standard in 2022. The framework comprises five dimensions—digital awareness, digital technology knowledge and skills, digital application, digital social responsibility, and professional development—and stands as a theoretical basis for the evaluation and research of local teachers' digital ability.

From an international perspective, the construction of the digital ability framework highlights the core role of teacher education in improving relevant abilities. Early models, such as the TPACK (technology-teaching-content knowledge) model, have laid the foundation for understanding the cross relationship between technology, teaching methods, and content in teaching practice (Maor, 2017; Lau, 2013). Subsequently, the framework gradually evolved into a more policy-oriented and measurable structure. An example is the Norwegian Framework for Teachers' Professional Digital Competency (PfDK), which integrates ethics, teaching methods, leadership, and social participation into the key elements of teachers' digital professional literacy (Kelentrić, Helland & Arstorp, 2017).

At the European level, the DigCompEdu framework designed by the Joint Research Center of the European Commission (JRC) presents a paradigm model that matches teaching capacity with the educational challenges of the 21st century (Caena & Redecker, 2019). Empirical verification research confirms its reliability and wide recognition. For instance, an expert evaluation of seven frameworks found that DigCompEdu is the most comprehensive and balanced model of teaching, followed by Spain's INTEF framework (Cabero-Almenara, Romero-Tena & Palacios-Rodr ǵuez, 2020). The comparative analysis further showed that these frameworks are convergent in the field of competence, such as information management, communication, collaboration, content creation, ethics, and problem solving, but their focus may vary according to the respective educational situations (Mattar, Santos & Cuque, 2022). Outside Europe, China's online teacher training model based on TPACK denotes how the digital teaching framework can be localized and integrated into the teachers' professional development system (Huang, 2021). Recent research also pointed out that pre-service teacher education increasingly adopts such frameworks to ensure consistency between theory, technical practice, and competency assessment (Rakisheva & Witt, 2023).

Overall, these frameworks reflect the transformation of teacher education from fragmented

ICT skill standards to a holistic model focusing on teaching integration, ethical responsibility, and lifelong digital learning. The framework divides teachers' digital ability into six dimensions and places special emphasis on the core area of "empowering learners". Its central position has been verified through meta-analysis research (Cabero-Almenara et al., 2022). Furthermore, the "Teachers' Digital Competency Framework" released by Spain in 2022 divides the field of competence into five aspects: information and data literacy, communication and collaboration, digital content creation, security standards, and problem solving.

Comparative research shows that different education systems will form differentiated focuses according to their needs and cultural backgrounds, thus affecting the actual perception of teachers' own digital abilities and skills (Mardiana, 2024). For example, the Chinese framework emphasizes digital social responsibility, the EU framework is oriented towards learner empowerment, and the Spanish framework focuses on universal digital capabilities. Although this diversity contributes to the localized adaptation of education systems worldwide, it may also lead to a lack of uniformity in the digital ability standards of global teachers, ultimately posing a challenge to transnational collaboration and resource sharing (Rodríguez García & Olivares, 2023). Although these frameworks define what digital capabilities should contain, numerous studies have investigated the actual status of teachers' digital capabilities, and the results often reveal significant challenges and shortcomings.

2.2 Research on the Current Status and Problems of Teachers' Digital Competency

Researchers have employed various approaches to gauge the status of teachers' digital competency, with the results showing that teachers' self-rated digital competency does not coincide with their actual levels of competency. An empirical study in China's higher education reported that the distribution of digital competencies among university teachers remains unfair, denoting a major gap between technical competence and pedagogical use (Feng & Sumettikoon, 2024). Pettersson (2020) also observed that teachers usually possess some degree of technical competence but often face difficulties in translating it into teaching practice. This issue can be attributed to inadequate availability of resources and insufficient development of digital pedagogy.

According to Spante et al. (2018), there is a long-term conceptual ambiguity between digital literacy, ICT competence, and digital competence, which makes international benchmark comparisons and empirical evaluations complicated. The systematic review of Gutiérrez-Ángel et al. (2022) analyzed the empirical research of more than ten years and found that most college projects emphasize self-efficacy and learning motivation rather than verifiable performance results, thus overestimating the real ability level of teachers.

Regarding research methods, González-Mujico (2024) warned that in digital ability research, the use of self-assessment questionnaires often leads to inflated high scores, which may not reflect the actual classroom teaching. The author introduced a rubric-based framework combined with external evaluation and task performance analysis to overcome the limitations of subjective data. It revealed more accurate measurement results towards the digital ability of students and teachers.

Overall, these findings demonstrate that although digital capabilities have become the focus of education policy, the methodology of empirical assessment remains vulnerable. Over-reliance on perception-based measurement tools masks key differences in teaching applications, leading to what Gutiérrez-Ángel et al. (2022) called the "confidence-competence gap". Future research must introduce multi-dimensional measurement models to integrate self-assessment, external observation, and performance-based evidence. Such triangular verification methods are crucial to accurately identify the real state of teachers' digital ability and design more effective interventions in the context of higher education.

2.3 Research on Factors Influencing the Formation of Teachers' Digital Competency

Scholars also pay attention to the endogenous and external variables that affect the development of teachers' digital ability. Sánchez et al. (2020) conducted a quantitative study by administering a questionnaire survey to 520 Spanish teachers. The data were analyzed using descriptive and correlation analyses to explore the correlation between internal factors (gender, age, teaching experience, education level, and training proficiency) and teachers' digital ability. Additionally, the impact of external environmental factors cannot be ignored. Maran et al. (2022) highlighted that the rapid iteration of technology and the wide application of digital tools constitute the key exogenous driving force. They also found a significant contradiction between the market's urgent demand for teachers with high digital literacy and the lack of support in the existing training system.

In general, studies on internal and external factors have emphasized the importance of their respective dimensions, and the two are essentially complementary. However, these studies have limitations: the former relies on self-reported data and has a risk of deviation, while the latter fails to propose specific improvement plans. Therefore, it is necessary to conduct empirical verification research in a broader and more dynamic situation to systematically analyze the formation mechanism of teachers' digital ability and its optimization path.

2.4 Research on Strategies to Improve Teachers' Digital Competency

In terms of improvement strategies, research on teachers' professional development has shifted from isolated training projects to a more comprehensive and evidence-based framework. Howard et al. (2021) proposed "Synthesis of Qualitative Evidence (SQD)", which identifies six interrelated teaching strategies: role model demonstration, reflection, design-based learning, collaboration, real experience, and feedback. Together, these strategies promote the development of digital ability among pre-service teachers. The large-scale empirical analysis of 931 students found that the multi-way integration method combining demonstration, real practice, and reflective feedback can bring the most sustainable improvement in digital capabilities.

On this basis, Tondeur et al. (2018) emphasized that effective digital ability training should operate at the macro (e.g., institutional leadership, resource security) and micro levels (e.g., teaching design, feedback culture). It also advocates the construction of a systematic and continuous professional learning ecosystem and non-sporadic training workshops. Malykhin et al. (2020) also advocated that self-assessment and reflection are important self-regulation

strategies for college teachers. This can help them identify individual ability gaps and make personalized improvement plans through mixed learning and reflection logs.

Recent research has further expanded to the psychological and identity dimensions of teachers' digital ability. Bülbül and Özelçi (2025) reported that mobile learning motivation plays an intermediary role between digital literacy and teachers' professional identity, showing that professional learning with technical support can strengthen technical proficiency and enhance teachers' self-identification as "digital educators". Alqurashi (2023) found that teachers' self-confidence to use technology can be a good predictor of their willingness to participate in continuous professional development and adopt new ways of teaching, as evidenced by the validity of the self-efficacy scale of teachers' digital competence. Howard et al. (2021) and Bülbül and Özelçi (2025) summarized that long-term digital skills development depends not only on how frequently new technology and training are provided to teachers, but also on how it can motivate them and change how they teach in the 21st century.

Overall, these studies demonstrate two alternative ways of promoting teachers' digital skills development. External collaboration strategies, involving institutional collaborations, structured mentoring systems, and cross-school professional networks, work synergistically with internal motivation strategies, involving the development of reflective awareness, digital identity, and self-efficacy. Consequently, efficacious strategies should consider situational factors, individual preparedness, and organizational support as interconnected components within an integrated model that promotes the digital transformation of education.

2.5 Summary of the Literature Review

Existing literature on teachers' digital competence shows considerable progress in the field of educational modernization, from the construction of theoretical systems like DigCompEdu, HeDiCom, and China’s Teachers' Digital Literacy standard to empirical studies of teachers' practical performance. It denotes scholars’ gradual recognition of digital ability as the key connotation of educational modernization. These theoretical frameworks serve as valuable references to comprehend the current level and priority of global countries, including the empowerment of learning advocated by Europe to the social responsibility promoted by China. This suggests that digital capability is not an inherent fixed concept, but rather a culture adaptable and situational.

Although great progress has been made at the theoretical level, there are still limitations in current empirical research. Many studies rely heavily on self-reported questionnaires, and it is difficult to accurately reflect the real technical proficiency or teaching integration ability of teachers. In addition, comparative studies mostly focus on the K-12 education stage, while attention to higher education is relatively insufficient. China's existing research mainly focuses on the policy level or the overall situation of digital literacy, while overlooking the systematic assessment of the intrinsic mechanism of digital ability among college teachers. There is also a lack of strategic suggestions based on evidence in line with the reality of colleges and universities. These research gaps hinder the transformation of conceptual frameworks into operational teacher development models and curriculum design schemes.

Therefore, this study aims to address the above shortcomings through an empirical analysis of college teachers in Zhejiang Province. The research objectives include identifying key internal and external factors affecting teachers' digital capabilities, evaluating the effectiveness of existing training and support mechanisms, and proposing targeted sustainable improvement strategies. By integrating theoretical and practical perspectives, this research hopes to provide academic support for the local development of teachers' digital ability framework and cultivate the continuous digital transformation of China's higher education.

3. Research Method

3.1 Research Design

This research adopted a quantitative research method with principal component analysis (PCA) as the core. As a multivariate statistical technique, PCA is mainly used to identify and summarize the core dimensions of a set of related variables (Watkins, 2018). This method is applicable to the main goal of this study, namely to explore and extract key components of the professional ability of teachers in colleges and universities in Zhejiang Province, rather than verifying the preset theoretical model.

3.2 Participants and Sampling

The participants of this study encompassed 84 college educators from Zhejiang Province, China. The data were gathered through an online survey, which elicited information like gender, years of teaching experience, level of education, academic rank, and field of specialization.

3.3 Instrument

This study used a questionnaire as the instrument for data collection. The first part gathered the respondents' personal information, including gender, years of teaching experience, level of education, academic rank, and subject area. The second part was developed based on the literature review and the conceptual model of teachers' digital competence (Janssen et al., 2013; Instefjord & Munthe, 2017). It elicited data regarding digital competence, teaching ability, school climate, and professional development, which were measured using a 5-point Likert scale ranging from "1 = Strongly Disagree" to "5 = Strongly Agree".

3.4 Data Gathering and Analysis

The data were collected by distributing the questionnaire online via the Wenjuanxing platform, a widely used online survey tool for academic research in China. All respondents answered the questionnaire individually and their responses were automatically stored in a digital database. The data were then downloaded to IBM SPSS Statistics for further analysis. First, descriptive statistics were employed to identify the respondents' demographic profiles. It was followed by the principal component analysis of the four modules (i.e., digital competence, technical ability, school atmosphere, and professional development) to identify the basic dimensions of teachers' digital competence. PCA is an effective method to reduce data dimensions and identify the main components explaining most of the total variance (Sánchez et al., 2020). Once the principal components were extracted, Varimax rotation was implemented to make the

structure more understandable. This orthogonal rotation method would maximize the variance of squared loadings over all components, making each variable to have a high loading on one single component and small loadings on the others. This will improve the clarity of the component structure (Watkins, 2018).

Both the Kaiser-Guttman criterion and Cattell scree test were employed to determine the number of components to keep. The former retained components with eigenvalues higher than 1.0, while the latter used the inflection point in the scree plot to find the best solution. Both methods reserved two components, which provided the most economical and significant depiction of the data structure (Watkins, 2018). Using the rotated component matrix, all items were sorted into groups according to their highest loadings. Cronbach's alpha coefficients were then calculated for all groups to identify the consistency of the items. Following the criterion suggested by Sánchez et al. (2020), an alpha coefficient of ≥ 0.70 was accepted, indicating that all the items measured one single consistent and reliable construct in each component. The results of these analyses served as the empirical basis for constructing a validated dual-dimensional framework of teachers' digital competence.

4. Results

4.1 Sample Characteristics

The sample of this study comprised 84 college teachers from Zhejiang Province, China. Figure 1 shows the demographic characteristics of the respondents. Their gender distribution is relatively balanced, with women accounting for 52.4% and men with 47.6%. This distribution suggests an equitable gender representation among the surveyed teachers.

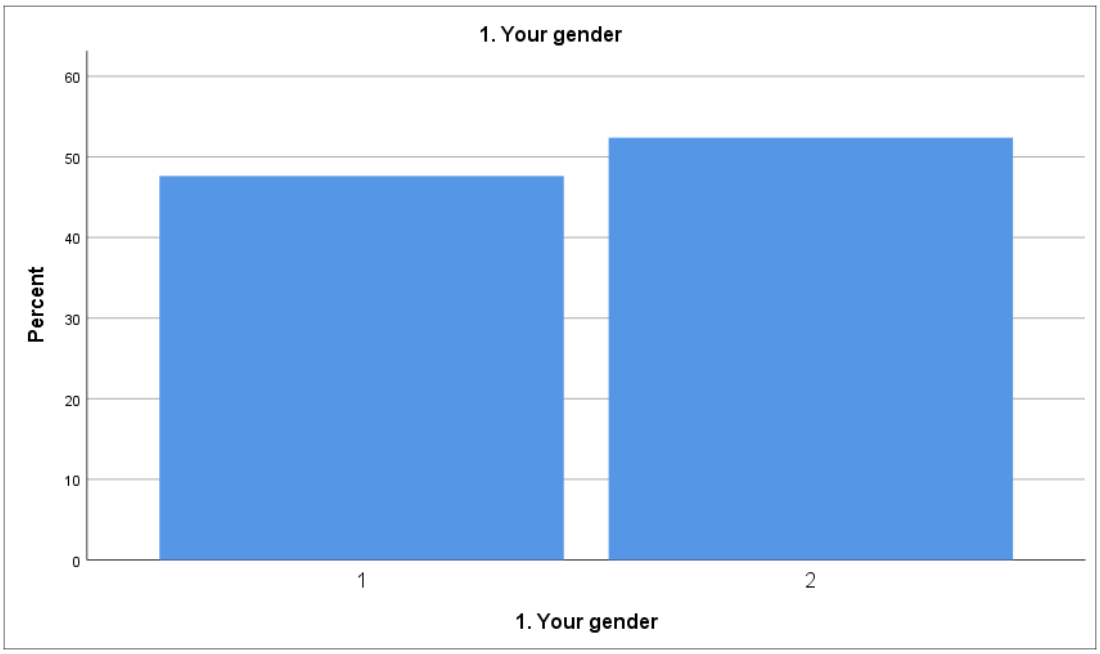

Figure 1. Distribution of Respondents by Gender (n=84)

In terms of teaching experience, the sample covers a wide range of career stages. The proportion of teachers with less than five years of teaching experience is the highest (34.5%), while a considerable share (22.6%) has over 20 years of teaching experience, indicating that the respondents represent both early-career and veteran educators (Figure 2).

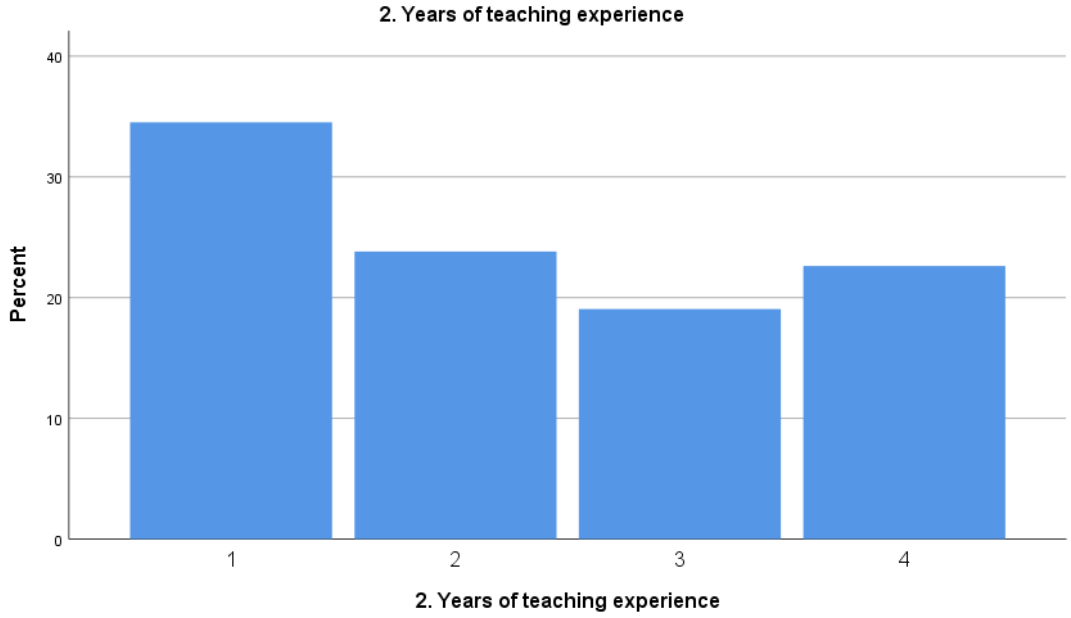

Figure 2. Distribution of Respondents by Years of Teaching Experience (n=84)

Regarding educational background, the respondents are generally highly educated. The majority hold a Master's degree (67.9%) and a doctoral degree (27.4%), reflecting a well-qualified academic workforce in the sample (Figure 3).

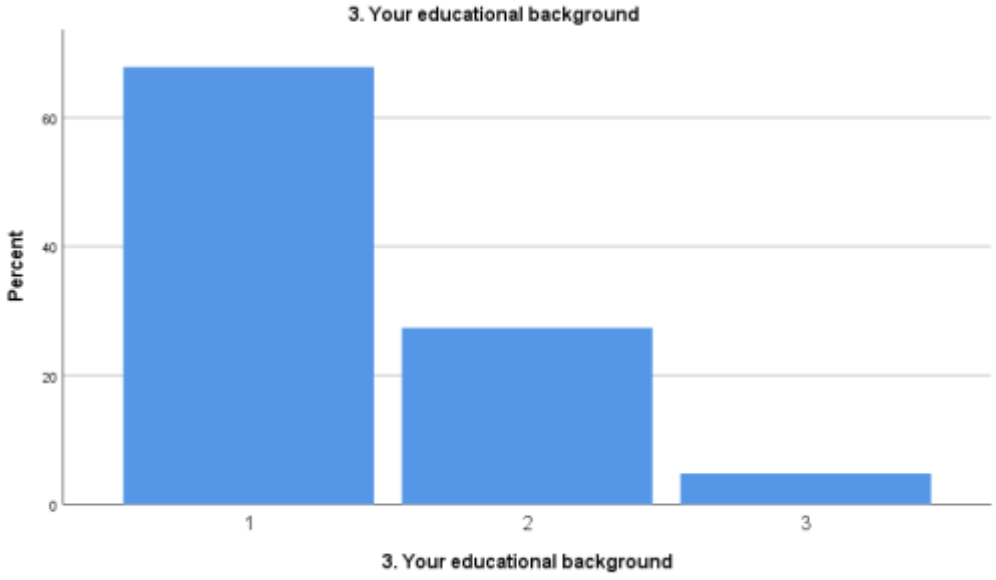

Figure 3. Distribution of Respondents by Educational Background (n=84)

For academic ranking, the largest proportions are associate professors (38.1%) and lecturers (34.5%), suggesting that the majority of participants occupy mid-level teaching positions (Figure 4).

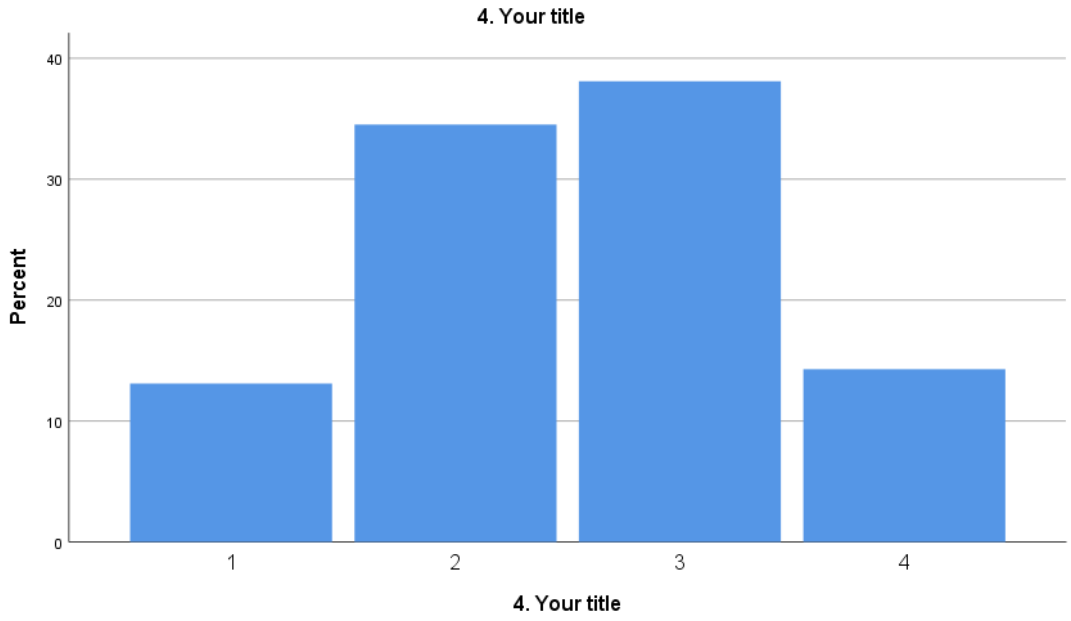

Figure 4. Distribution of Respondents by Title (n=84)

In terms of disciplinary distribution, the majority of respondents were social sciences teachers (65.5%), followed by natural sciences (11.9%), humanities (9.5%), and other fields (13.1%). This distribution shows that the sample mostly comprised teachers who studied social science (Figure 5).

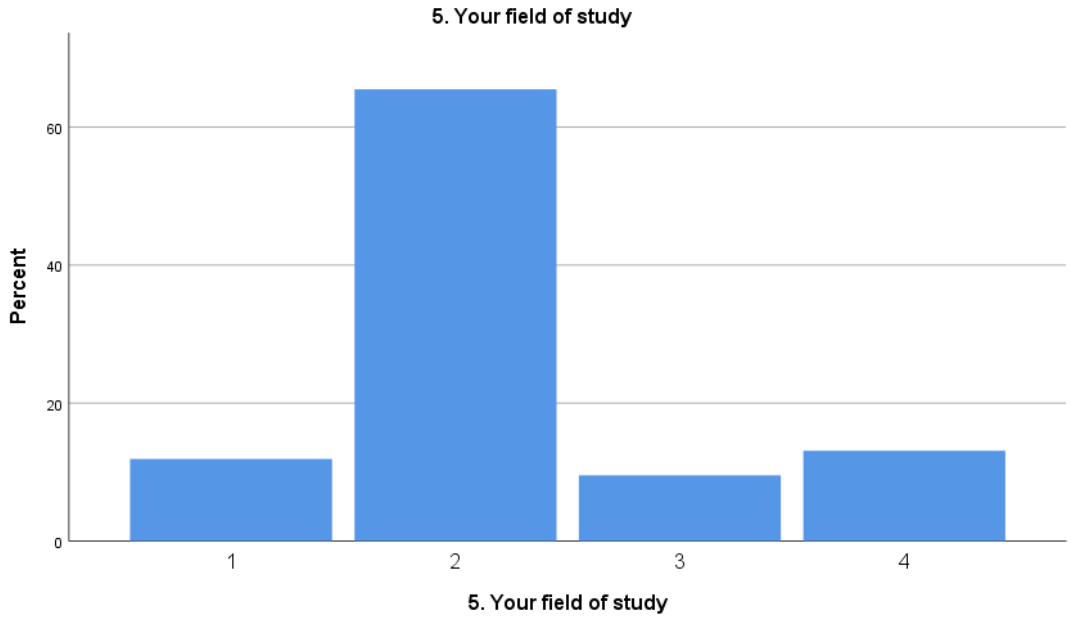

Figure 5. Distribution of Respondents by Field of Study (n=84)

The demographic profiles of all 84 participating teachers constitute a representative and meaningful distribution in terms of gender, years of teaching experience, academic qualifications, and professional status. The diversity in academic qualifications, comprising mainly social sciences and other fields, denotes a broad spectrum of opinions regarding digital competence in higher education in Zhejiang. This diverse distribution provides a foundation for later studies of the hidden dimensions of teachers' digital competence and institutional support.

4.2 Data Suitability and Analytical Approach

Before analyzing the main components for the investigation, it is crucial to verify the adequacy of the data set to ensure the goodness of the analysis (Ng et al., 2024; Watkins, 2018; Marín & Rivera Vargas, 2024). This study used principal component analysis (PCA) as the main analysis method while adhering to the established procedures for the validation of measurement tools and multivariate research (Ng et al., 2024; Watkins, 2018; Marín & Rivera Vargas, 2024). In contrast with exploratory factor analysis (EFA), the main component analysis aims to obtain a set of linear combinations that maximize the total variance of interpretable data, thus revealing possible ideas (Howard, 2023; Nabhan & Habók, 2024). This method generates a more concise and understandable structure by reducing the dimension of the data while maintaining important information (Sánchez et al., 2020).

The IBM SPSS Statistics software was used to statistically analyze the data in this study. Principal component extraction was conducted to obtain the main components with the most variation in interpretation, followed by the maximum variance orthogonal rotation method (Varimax Rotation) for easier interpretation of the model. The rotation method maximizes the variance of the square load of each component, meaning that the variable has a high load on one main component and a low load on other main components. This reduces the cross-load, making the factor structure easier to understand and the concept clearer (Watkins, 2018).

Furthermore, the analysis results showed that the correlation between the questions and the level of shared variance of the data set generally met the requirements of principal component analysis. The total variance explanation table demonstrated that the characteristic values of the first four main components are greater than 1.0, adding up to 53.05% of the total variance. However, the Scree Plot denoted a clear flattening trend after the second component, indicating that most of the explanatory variances had changed from the first two captured by the components.

A two-component solution was also found to be the best model based on the distribution of eigenvalues and the shape of the scree plot. This model was both statistically consistent and theoretically sound. Two components were extracted, namely Digital Teaching Competence and Institutional Support and School Climate, thus forming the main parts of a college teacher's professional competence. Together, these dimensions illustrate the foundation of a professional ecosystem that connects individual skills with the workplace, showing how personal digital skills and institutional support systems coexist in a dynamic way.

4.3 Determination of the Number of Components

Determining the optimal number of retained components is a key step in principal component analysis as it will directly affect the interpretability and conceptual validity of the extracted structure. This study combines two widely recognized judgment criteria to guide decision-making: the Kaiser-Guttman standard (i.e., Kaiser rule) and the Cattell Scree Test.

According to the Kaiser rule, only components with eigenvalues greater than 1.0 are retained, because each component should be able to explain the variance of at least one standardized variable. Meanwhile, the gravel test draws the eigenvalues of each component in descending order into a curve to provide a basis for visual judgment, in which the curve has an obvious "elbow the position of the part" (i.e., the inflection point where the slope begins to be flat), indicating the optimal number of components (Watkins, 2018).

The PCA results showed that the characteristic value of the four principal components was greater than 1, with a cumulative variance contribution rate of 53.05%. However, Figure 6 illustrates that the gravel diagram has an obvious inflection point after the second component and the curve tends to be flat. This trend shows that the first two principal components captured most of the explanatory variance, while the subsequent components contributed less to the overall structure.

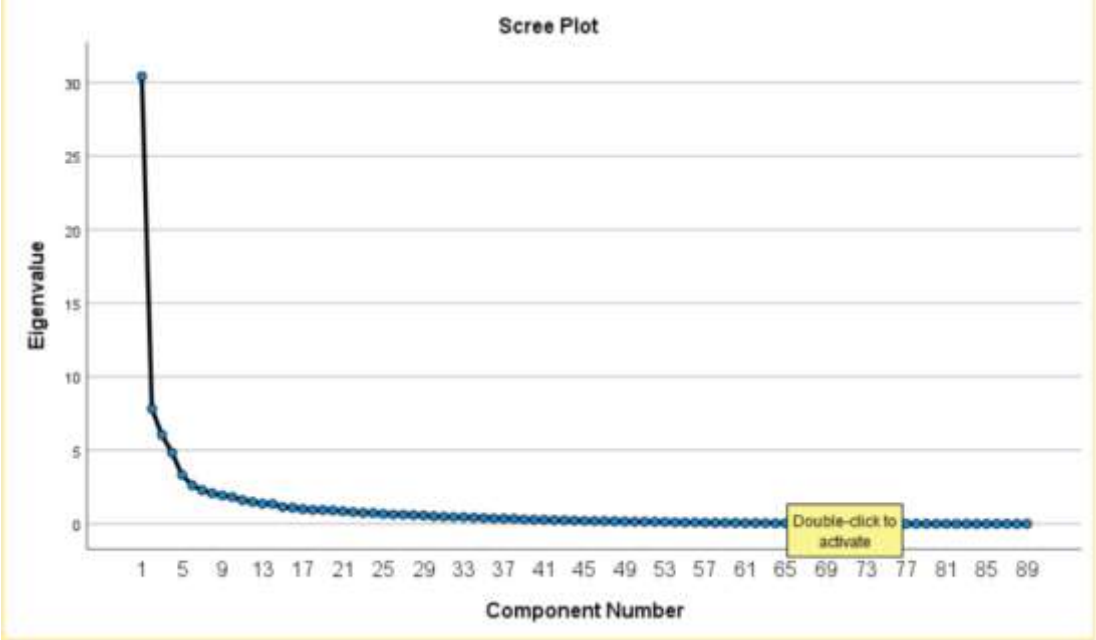

Figure 6. Scree Plot for Determining the Optimal Number of Components in PCA

(Source: IBM SPSS Statistics output)

This study found that the best fit for data is a two-component solution according to consistency criteria, which consists of statistical results (eigenvalue distribution evidence) and visual evidence (scree plot descent method). The first part was named Digital-Pedagogical competence, denoting the extent to which teachers can use technology in their lessons, adapt their teaching, and teach with technology. The second part was named Institutional Support

and School Climate, exploring the extent to which teachers can work with each other, stay motivated, and develop their profession within a larger organizational environment. These components can work together as a clear and simple structural model that combines individual ability and context support within a professional ecosystem of higher education teachers.

4.4 Factor Structure and Reliability Analysis

This section presents the results from the principal component analysis and the internal consistency reliability analysis to verify the dimensional structure of the measurement instrument. First, the PCA with Varimax rotation yielded a two-component solution. The Total Variance Explained (see Table 1) indicates that the two components explained 42.95% of the total variance after rotation (Component 1 = 23.62%, Component 2 = 19.33%). Such results are clear and simple to interpret the factor structure.

Component 1 was formed by 52 items regarding Integrated Digital Pedagogical Competence (IDPC). This dimension reflects how teachers manage teaching, curriculum, and assessment with digital tools. It also explores their usage of technology in creative and meaningful ways to enhance the learning process and outcomes within boundaries characterized by good teaching. On the other hand, Component 2 comprised 33 items, which reflected both institutional and interpersonal factors, such as school support, work climate, collegial collaboration, and reflective practice. This dimension denotes the context and ecological factors that support teachers' continuous learning and engagement in digital teaching.

Table 1. Total Variance Explained (Principal Component Analysis)

Component	Initial Eigenvalues	% of Variance	Cumulative %	Rotation Sums of Squared Loadings	% of Variance	Cumulative %
IDPC	30.411	34.170	34.170	21.025	23.623	23.623
CPE	7.813	8.779	42.949	17.200	19.326	42.949

Subsequently, Cronbach's alpha (α) coefficients were employed to determine the strength of each relationship. Both IDPC (α = .965, N = 52) and CPE (α = .949, N = 33) recorded high reliability coefficients, exceeding the threshold of 0.70. This reveals that the items are highly consistent with each other and measure consistent hidden variables correctly. PCA and Varimax with Kaiser Normalization were used in the extraction process and rotation method, respectively, thus allowing for easier interpretation of the components' content. Table 2 shows the statistical structure components, question counts, and reliability coefficients.

Table 2. Factor Structure and Reliability Summary

Component	Description	N of Items	Cronbach's α
DIPC	Technological–Pedagogical Competence (digital integration, instruction, assessment)	52	.965
CPE	Institutional & Professional Development Context (work climate, collaboration, reflection)	33	.949

IDPC comprises all the skills that teachers possess within the sphere of using digital tools in a pedagogically purposeful way for teaching and assessing. It shows the dynamic relationship between technological knowledge and instructional design and how teachers use digital tools on purpose to enhance student learning. Teachers utilize digital tools not merely for using technology, but for choosing, adapting, and organizing technology in a way that is congruent with the goals of the curriculum and the realities of classroom practice. IDPC denotes how far teachers will go in transforming a digital tool into a potentially powerful learning experience.

Three interconnected dimensions can be discerned in this construct. First is digital integration, which refers to the ability to ensure that the right digital tools are in line with lesson goals and learning tasks so that students can be actively involved in learning. Second is instructional design and delivery, which means that teachers can plan, conduct, and keep track of technology-enhanced learning activities that help students understand and interact with each other. The third dimension is technology-based assessment, which demonstrates how well teachers can use the digital platform for formative and summative evaluation so that they are able to make sense of the data and decide on how to teach in the future. Together, these three dimensions encompass the essence of teachers' enacted technological-pedagogical knowledge in authentic settings and how innovative teachers integrate digital tools purposefully into teaching.

CPE represents the institutional and interpersonal context that supports teachers to learn, work together, and reflect on their work in digitalized educational settings. It highlights how organizational structures, leadership culture, and peer relationships work together to keep teachers growing and generating new ideas. Conversely, this context supports teachers to improve and use their teaching and technology in the best way. This construct delineates three interconnected components. First is work climate and leadership, which reflects how much support the administration provides, how well people share a vision together, and how open the school is to new ideas and initiatives. Second is peer collaboration, which means working together with other professionals to learn from each other through collegial exchanges, co-teaching, and group problem-solving. Third is reflective professional learning, which means that teachers have the chance and the desire to have reflective conversations and make improvements based on questions within their professional community. These components

collectively constitute an ecology that fosters educators' sense of belonging, empowerment, and dedication to the transformation of digital pedagogy. Figure 7 illustrates a conceptual representation of the two primary dimensions—IDPC and CPE—to demonstrate the connection between teachers' implemented digital pedagogical competencies and the institutional professional ecology supporting them.

Figure 7. Components of IDPC and CPE

IDPC and CPE are the dynamic building blocks that make it possible for ICT to be used in schools in a way that lasts. These two dimensions are different in theory but similar in practice: IDPC represents the technological and pedagogical knowledge that a teacher uses, and CPE represents the institutional and social environment that complements, reinforces, and extends that knowledge over time. When these two dimensions work together, there is a multiplying effect that results in deeper changes in teaching and long-term use of digital tools in the classroom.

A strong CPE makes the conditions suitable for teachers to continue improving their IDPC, which is influenced by their leader, the way they work with other teachers, and the feedback they receive after implementing something new. In other words, teachers working in a professional environment continue to improve their digital pedagogical knowledge and skills, try out new digital tools, and receive feedback that helps them use technology in a context where it makes sense. On the other hand, a teacher with a strong IDPC provides a professional ecology with good practices to emulate, mentors other teachers, and invites them to use new digital tools. The interdependence between these two dimensions strengthens the learning and adaptation cycle in an institution and transforms what began as individual digital use into group pedagogical use, making the digital learning practice sustainable, long-lasting, and scalable.

The synergy between IDPC and CPE shows that successful integration of ICT is not only an individual process of development and learning, but also a process that requires the appropriate support and a shared professional culture. A well-balanced system is scalable and transformative, in which teachers have strong digital-pedagogical skills, work in a professional environment with adequate support, collaborate with other teachers, learn from their mistakes,

and are able to use digital tools in a way that makes learning last. This interdependence shows that, in practice, the model is comprehensive and describes ICT integration as an individual educational process and as a socially supported and institutionally facilitated process.

Finally, the results of the principal component analysis and reliability tests showed that the measurement instrument has a stable and comprehensible two-dimensional structure. The model extracted from the data, formed by the two parts, presents good statistical validity and regularity from a theoretical point of view. The two parts present a high level of internal consistency, and the factor loadings are clear and comprehensible. Thus, the instrument is suitable to be used to measure the main aspects of teachers' digital competence in higher education settings. These results provide a solid base for ensuing discourse, model extension, and theoretical clarification.

5. Discussion and Conclusion

5.1 Summary of Research Findings

The PCA results revealed two underlying components that together represent the essence of the digital competence of higher education teachers. It denotes that competence should not be understood as consisting of four separate modules, but as an integrated whole, comprising IDPC and CPE. Together, these two components explained 42.95% of the total variance, suggesting that the instrument can capture both the individual (IDPC) and contextual (CPE) levels of the professional capability of teachers. This structure shows that the technological-pedagogical ability of the teachers and the institutional-professional environment are two interrelated and mutually exclusive dimensions of an integrated competence level.

The first principal component explains teachers' capability to use digital technology for their lessons at an individual level. It displays important professional skills, such as digital teaching methods, instructional design, online assessment, and using educational technologies in a flexible way. This part fits well with the global call for teachers who are digitally literate and creative in their teaching (Marian et al., 2022). The second principal component includes the contextual and organizational elements that influence the performance of teaching at an institutional and developmental level, including school support systems, collaborative work environment, transparent decision-making, and organized ways for professional development. These results demonstrate that the professional competence of teachers is not based on their own skills, but on the condition at the school encourages active participation, motivation, and further professional initiative.

In summary, the PCA results provide a strong empirical basis for a two-dimensional competence model for higher education instructors. The first dimension explains how well teachers are able to use digital technology for their lessons, and the second dimension explains how the institution supports the professional growth of teachers. The model demonstrates how individual capability (IDPC) and systemic support (CPE) influence teachers' ability to perform in relation to technology-enhanced learning.

5.2 Theoretical and Practical Contributions

This study contributes to the literature on the digital skills and professional development of higher education teachers by responding to the pressing demand for analytical frameworks that have been applied in real life (Reddy et al., 2023). Unlike conventional studies that distinguish teachers' technical skills from wider pedagogical and institutional influences through a separation analytical framework, this research uses a systemic analytical framework that includes digital pedagogy, technological innovation, and contextual support. The validated two-dimensional model developed in the context of higher education in China advances the local adaptation of global digital competence frameworks and contributes to the body of empirical evidence documented in recent regional studies (Feng & Sumittikon, 2024). Furthermore, the use of principal component analysis guarantees a statistically validated confirmation of the proposed construct and provides a theoretical basis for understanding the multidimensional aspects of teachers' professional competence. This study offers a repeatable way for future research to integrate pedagogical, technological, and institutional points of view in understanding teacher competence by connecting theory-driven frameworks and data-driven evidence.

The findings of this study have important implications for policy formulation, institutional strategy, and professional development programs. The validated dual-component framework provides a concise but comprehensive basis on which policymakers and institutional leaders can base their evaluations and improvements of teacher competency standards, recruitment strategies, and evaluation systems. Our results indicate that good teacher development should focus not only on improving technical skills and teaching skills but also on establishing a positive school culture and work environment where people work together. This is consistent with modern ideas about how to train teachers that highlight the importance of practice, structured reflection, and working with peers (Hasanah et al., 2022). Moreover, the proposed framework can serve as a diagnostic instrument for teachers' self-evaluation to promote the identification of their strengths and areas for improvement. Teachers are encouraged to promote self-directed learning and reflective practice by reflecting on their digital-pedagogical competence and their involvement in institutional learning environments. This aligns with the educational community's growing recognition of lifelong learning and professional autonomy (Reddy et al., 2023).

5.3 Limitations and Future Research

Even though the study achieved its main research aims, some issues should be acknowledged and reflected upon in future research. Primarily, the participants came from higher education institutions in Zhejiang Province. While it provided valuable localized information, it limited the generalizability of the findings to other educational contexts. Second, the relatively small sample size (N = 84) suggests that the results should be considered exploratory (Kunselman, 2024). Future research should use a larger and more diverse sample from diverse institutional and cultural contexts to further support the validity and universality of the two-dimensional model with IDPC and CPE.

From a methodological perspective, this study mainly used self-reported questionnaire data, which might be subject to subjective bias and social desirability effects. Jung, Choi, and Fanguy (2024) argued that enriching questionnaire data with qualitative evidence, such as classroom observations and interviews or analysis of documents, would help to gain a deeper understanding of how teachers' IDPC manifests in practice and how CPE affects teachers' engagement and motivation. Moreover, due to the cross-sectional design of this study, the results reflect only a snapshot of teachers' competence and institutional context at a certain point in time. With the rapid development of digital educational environments, longitudinal studies in the future should explore the joint development of teachers' technological competence and pedagogical competence as well as institutional support systems simultaneously, especially in the post-pandemic period (Tomczyk & Fedeli, 2022).

Future research may employ cross-regional and cross-cultural comparisons to explore the applicability and stability of the IDPC-CPE framework in other educational contexts. The use of mixed-methods approaches, which combine the results of quantitative validation methods (e.g., PCA or CFA) with qualitative methods (e.g., focus groups or narrative inquiry), can achieve methodological triangulation and enrich the interpretive understanding of the dynamic interplay between teachers' individual competence and their institutional ecology (Temirkhanova et al., 2024). Longitudinal case studies following teachers across more than a few academic years might provide interesting findings regarding the interplay between the digital and institutional reform forces in the long-term development of teachers' professional competence in a dynamic educational environment.

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