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What are the determinants of rural-urban divide in teachers' digital teaching competence? Empirical evidence from a large sample

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The digital divide between rural and urban areas is becoming the key factors resulting educational imbalance, which might be exacerbated by differences in teachers' digital teaching competence. Therefore, it was crucial to explore the divide and determinants of digital teaching competence between rural and urban teachers. A large-scale survey was conducted with 11,784 K–12 teachers in China (43.40% from rural schools and 56.60% from urban schools). First, this study investigated potential factors for teachers' digital teaching competence, including information and communication technology (ICT) attitude, ICT skills, and data literacy. Second, the data indicated the digital divide existed, i.e., the ICT attitude, ICT skills, data literacy, and digital teaching competence of rural teachers were significantly lower than those of urban teachers. Third, the Blinder-Oaxaca decomposition method demonstrated that data literacy and ICT skills were the most important determinants of the divide in digital teaching competence between rural and urban teachers. Hence, our research provided important insights for policymakers, school leaders and teachers to bridge the digital divide.

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Introduction

Ensuring inclusive and equitable quality education for all, as Sustainable Development Goal 4 (SDG 4), was called for urgent attention around the world (United Nations, 2022; The Word Bank, 2022). Information and communication technologies (hereinafter, ICT), which had the potential to achieve universal access and transform education (Timotheou et al. 2022), were considered as a promising solution to advance equity in education (Luo et al. 2022a). However, the rapidly growing ICT also posed challenges to education, that was, the risk of further digging the digital divide. With the gradual popularization of ICT infrastructures, the digital divide took on different shapes (van Dijk, 2006). The first-order digital divide referred to the differences in access to the internet and digital technologies (van Dijk, 2020). The second-order digital divide was based on digital competence and use (Corkin et al. 2022; Castaño Muñoz et al. 2022; Goudeau et al. 2021; Aissaoui, 2022). The third-order digital divide was the difference in the results of benefiting from the use of digital technology (Zhao et al. 2022; Lutz, 2019; Ragnedda and Ruiu, 2017).

However, some studies showed that the rural-urban digital divide in education was still complicating and growing even with better ICT infrastructures (Dolan, 2016) . Given the global context, the United Nations (2022) reported that entrenched inequalities in education only worsened, with a deep divide between rural and urban areas, one of which was the skills to use digital technologies, such as computers. The digital competence divide, as the second-order digital divide, was a persistent barrier to education in the digital age (UNESCO, 2021). Bridging the digital divide was also a huge challenge for teachers (Creighton, 2018), and enhancing the quality of teachers in rural schools was often cited as a key strategy (Luo et al. 2022b). If teachers lacked the competence to integrate digital technologies in teaching, it would be meaningless to bridge the first-order digital divide with completed ICT infrastructures. Digital teaching competence implied the acquisition of a set of skills, knowledge, and attitude that teachers must possess for the technical, pedagogical, and didactic incorporation of ICT in educational contexts (Cabero-Almenara et al. 2021). Existing studies found that teachers' digital teaching competence had a direct positive impact on empowering students (Aydin, 2022; Lin et al. 2022), and there was still a lot of room for improvement in teachers' digital teaching competence (Gouseti et al. 2023; ElSayary, 2023; Yang et al. 2022; Antonietti et al. 2022). Therefore, how to improve teachers' digital teaching competence should be highly valued. What's more, most of the existing studies revealed the digital divide in digital competence from the perspective of students (Li et al. 2023; Weninger, 2022; Zhao et al. 2022; Liao et al. 2016), few studies focused on the current situation of rural teachers (Wu et al. 2022), and even less explored the differences and determinants between rural and urban teachers' digital teaching competence. While ICT infrastructures were being built, the rural-urban differences and determinants in teachers' digital teaching competence were clearly needed to become future-ready.

The research questions for the study include: (1) What are the potential factors that influence teachers' digital teaching competence? (2) Does the divide in digital teaching competence exist between rural and urban teachers? (3) If it does, what is the relative importance of the determinants contributing to the competence divide? The rest of this paper is structured as follows. Section "Literature review and hypotheses development" reviews the literature and processes the hypotheses. This section also provides details on prior studies to find the research gap, hence it motivates the interest in the differences and determinants between urban and rural teachers. Method section describes the instruments and datasets used in our research. Data is then analyzed in the Result. To be specific, we verify the instrument and measurement model, test the hypotheses and explore the determinants of rural-urban divide in teachers' digital teaching competence. In the Discussion, we discuss the results and answer three research questions. Finally, we conclude the paper and list the implications and limitations in the "Conclusion, implication, and limitation" section.

Literature review and hypotheses development

ICT attitude. ICT attitude, which determined whether teachers were willing to integrate digital technologies in teaching (Aslan and Zhu, 2017; Sang et al. 2011), was a prerequisite for teachers to carry out educational programs with digital technologies (Gupta and Singh, 2018). In previous research, ICT attitude was expressed as general feelings of support for or opposition to the use of ICT (Lin et al. 2022; Yuen and Ma, 2008). Some studies found that teachers' attitude would influence their behaviors in using digital technologies in teaching (Latorre-Cosculluela et al. 2023; Antonietti et al. 2022; Scherer et al. 2019; Simonsson, 2004; Huang and Liaw, 2005), as would their digital teaching competence (Hernández-Ramos et al. 2014; Drent and Meelissen, 2008). However, other researchers demonstrated that teachers' ICT attitude did not have a significant relationship with digital teaching competence (Lin et al. 2022; Gudmundsdottir and Hatlevik, 2018; Aslan and Zhu, 2017). Hämäläinen et al. (2021) also revealed that teachers still stayed low level in their competence with high level of ICT attitude. Due to the contradictions between existing studies, we wanted to explore this relationship through a large-scale investigation.

Geographic location of school was proven to be an essential variable for teachers to use digital technology (Chen et al. 2023; Liu and Teddlie, 2009). Keramati et al. (2011) showed that urban teachers had a positive attitude towards ICT use and could significantly influence their digital use. Compared with urban teachers, remote rural teachers tended to have more conservative teaching concepts (Wu et al. 2022). Even though rural teachers had a positive attitude towards ICT (Mahdum et al. 2019), teachers might be reluctant to digital use in the classroom. Therefore, this study speculated whether there was a difference in ICT attitude that led to divide in the digital teaching competence between rural teachers and urban teachers. Above all, we proposed the following hypotheses:

Hypothesis 1 (H1): Teachers' ICT attitude positively affect their digital teaching competence.

Hypothesis 2 (H2): Rural teachers show a lower level of ICT attitude than urban teachers.

ICT skills. ICT skills were seen as necessary conditions for using technology to improve teaching practices (Hamailainen et al. 2021; Knezek and Christensen, 2016), which referred to the use of hardware (e.g., computers, projectors, or visualizers) and software (e.g., social media, web platforms, or teaching tools in discipline). Prior studies showed that teachers' ICT skills had a significant impact on digital teaching competence (Lin et al. 2022) and were associated with the level of the teaching profession (Kaarakainen et al. 2018; Knezek and Christensen, 2016). Hatlevk (2017) also confirmed that assessing teachers' self-efficacy in basic ICT skills could predict changes in teachers' digital competence. Thus, if schools wanted to introduce digital technologies, they should ensure teachers maintained basic ICT skills (Ilomäki et al. 2016).

The technical environment for teachers in urban schools was more adequate so that urban teachers could teach more effectively than rural teachers (Mitchell and Nath, 2013; Wahyudi and Treagust, 2004). Studies showed, in Malaysia, that rural teachers had poor ICT skills compared to urban teachers (Khairani, 2017). Due to limited hardware and resources in rural areas, rural teachers were under great pressure to use technology (Gabr et al. 2021), hindering teachers' use of ICT in the classroom (Califf and Brooks, 2020). The ineffective use of hardware and software was what further exacerbated the divide in education between rural and urban areas (Wu et al. 2022; Li et al. 2020; Wang et al. 2019). For example, during the COVID-19 pandemic, online teaching was implemented on a large scale. Compared to urban teachers, Salemink et al. (2017) found that rural teachers were poor in technology use and lacked ICT skills. What's more, the rural-urban gap in ICT infrastructures was further narrowed in China. Based on previous research, it was valuable to explore whether there was a gap in ICT skills among rural and urban teachers under the premise of balanced infrastructure construction. Above all, we proposed the following hypotheses:

Hypothesis 3 (H3): Teachers' ICT skills positively affect teachers' digital teaching competence.

Hypothesis 4 (H4): Rural teachers show a lower level of ICT skills than urban teachers.

Data literacy. Data literacy for teaching referred to transform information into actionable instructional knowledge and practices by collecting, analyzing, and interpreting all types of data (Gummer and Mandinach, 2015). Most scholars described teachers' data literacy as including four dimensions: data collection, data analysis, data evaluation, and data application (Cui et al. 2023; Papamitsiou et al. 2021). Theoretically, teachers could cultivate their data literacy (Kennedy-Clark and Reimann, 2022; Cui and Zhang, 2021) to capture students' data and provide valuable feedback for teaching and learning in a data-rich environment (Cui et al. 2023; Gebre, 2022). However, existing research revealed that data literacy among teachers was generally lacking and still had large scope for improvement (Sun et al. 2016; Wu et al. 2021). In addition, Lin et al. (2022) investigated a small-size sample and found data literacy can significantly predict teachers' digital teaching competence. Therefore, it is necessary to reconfirm that conclusion based on the large-scale survey.

Digital technology with data might benefit rural areas (Tian et al. 2021), which would make data-driven teaching decisions increasingly personalized and intelligent. On the one hand, we took into account that rural teachers, who were inadequate use of digital technologies, might prevent them from collecting, analyzing, evaluating and applying data (Lin et al. 2022), demonstrating a low level of data literacy. On the other hand, there were few existing studies about data literacy in rural areas. For example, Conn et al. (2022) interviewed rural teachers who noted that data literacy was not mentioned in teacher assessment to collect data on how teachers improved their teaching based on the results of the assessment. Thus, it was obvious that the cultivation of data literacy was neglected for rural teachers. What's more, even less study discovered the divide on data literacy in rural-urban comparison. Therefore, it was urgent to explore the rural-urban digital divide in data literacy. Above all, we proposed the following hypotheses:

Hypothesis 5 (H5): Teachers' data literacy positively affects teachers' digital teaching competence.

Hypothesis 6 (H6): Rural teachers show a lower level of data literacy than urban teachers.

Digital teaching competence. Digital teaching competence, as the key to directly relate to empowering students (Lin et al. 2022), implied the acquisition of a set of skills, knowledge, and attitude that teachers must possess for the technical, pedagogical, and didactic incorporation of ICT in educational contexts (Cabero-Almenara et al. 2021). In Indonesia, Mahdum et al. (2019) investigated 616 rural high school teachers and found that they had a positive attitude and strong motivation to integrate information technology into their classrooms but rarely used digital technologies in their classrooms. Therefore, rural teachers were unable to effectively use digital technology and integrate it with teaching (Yang et al. 2018). Rural teachers had a low level of digital competence and were often considered as poor users of digital technologies (Dauvarte, 2015; Rana et al. 2018). In contrast, teachers in urban areas were equipped to fully integrate digital technologies in education (Yu et al. 2020). For example, Thannimalai et al. (2022) showed that significant difference in the use of digital technologies between rural and urban teachers. However, Zhao et al. (2022) confirmed that no significant difference in the level of digital support provided to students from rural and urban teachers. There were contradictions in existing studies, and whether there was a difference in the digital teaching competence of rural and urban teachers remained to be explored. Above all, we proposed the following hypothesis:

Hypothesis 7 (H7): Rural teachers show a lower level of digital teaching competence than urban teachers.

Digital divide in competence. Competence and use of digital technologies, as the second-order digital divide, were urgent needs to coordinate global efforts (van Dijk, 2006). On the one hand, existing studies identified some factors that widened the digital divide in competence, including gender (Estanyol et al. 2023), internal motivation (Zhao et al. 2022), location (Zarifa et al., 2019), ICT skills (Ben Youssef et al. 2022), access to digital technologies (Le et al. 2023), and social class disparities (Wei and Hindman, 2011) and so on. On the other hand, prior research on the relevant digital divide in education mainly focused on students (Corkin et al. 2022) and schools (Castaño Muñoz et al. 2022), while ignoring the teacher as the research object. Colicol and Colicol-Rodriguez (2023), conducted an ethnographic study, underscored the dynamic role of teachers in alleviating the digital divide between urban and rural areas and the need for teachers to have a voice in policymaking. Therefore, some studies explored the fact that there was the digital divide in teacher's competence, but a few delved into the factors that exacerbated the digital divide in teacher's competence. For example, Quaicoe and Pata (2020) focused on teachers' digital competence and revealed that corresponding digital activities related to professional roles would impact the digital divide in teachers' competence. What's more, the gaps in teachers' ICT attitude, ICT skills, and data literacy reflected that rural schools and teachers still show lower perception, lower competence and lag behind in access to digital technologies (Quaicoe and Pata, 2020; Soomro et al. 2020). However, there was little research to figure out the extent to which determinants affected the digital divide in teachers' competence.

Methods

Instrument measurement. The research instrument consisted of two parts. The first part was the demographic information of the participants, including gender, years of teaching experience, geographic location of school, and school level. The second part was four subscales, adopted from Lin et al. (2022), including ICT attitude, ICT skills, data literacy, and digital teaching competence.

Table 1 Instrument measurement.

Construct	Items	Description
ICT attitude (IA)	IA1	I recognize the importance of the application of information technology (IT) in modern education.
	IA2	I actively pay attention to the application and development of IT in education.
	IA3	I am willing to share with colleagues the experience and new discoveries about the application of IT.
ICT skills (IS)	IS1	I solve common problems in multimedia teaching equipment applications.
	IS2	I expertly use the information-based teaching equipment in the classroom (e.g., computers, projectors, visualizers).
	IS3	I expertly use at least one discipline-specific teaching tools (e.g., geometer's sketchpad, online maps, realistic experiments).
	IS4	I expertly use at least one social media and web platform to support students learning (e.g., e-mail, WeChat, MOOCs).
Data literacy (DL)	DL1	I efficiently retrieve and access raw data from the teaching process (e.g., access to data, databases).
	DL2	I reasonably use statistical analysis software to process and analyze the obtained data (e.g., SPSS, Excel).
	DL3	I judge the source, the collection method, and the quality of data to ensure accuracy.
	DL4	I analyze data to support teaching decisions and improve teaching strategies.
Digital teaching competence s(DTC)	DTC1	I select digital medias and resources based on different teaching sessions.
	DTC2	I use digital media based on different teaching sessions to enhance my teaching practice.
	DTC3	I provide targeted study recommendations based on the student level.
	DTC4	I choose the appropriate information-based teaching mode (e.g., project-based learning, resource-based learning, blended learning).
	DTC5	I provide effective digital technologies to support communication, collaboration, and exploration for students (e.g., learning guidance, learning process).

Table 2 Sample profile (*N* = 11,784).

Variable	Option	N	Percentage
Gender	Male	2400	20.37%
	Female	9384	79.63%
Years of teaching experience	1 - 5 years	3068	26.04%
	6 - 15 years	3731	31.66%
	16 - 25 years	2994	25.41%
	26 - 35 years	1746	14.82%
	More than 36 years	245	2.08%
Geographic location	Rural area	5114	43.40%
	Urban area	6670	56.60%
School level	Kindergartens	3532	29.97%
	Primary schools	4026	34.16%
	Secondary schools	2369	20.10%
	High schools	1227	10.41%
	Vocational schools	630	5.35%

Table 3 Principal component factor analysis with varimax rotation.

	Digital teaching competence	ICT attitude	ICT skills	Data literacy
DTC1	**0.850**	0.166	0.277	0.252
DTC2	**0.853**	0.163	0.278	0.265
DTC3	**0.859**	0.157	0.240	0.267
DTC4	**0.811**	0.161	0.249	0.361
DTC5	**0.812**	0.155	0.242	0.356
IA1	0.117	**0.859**	0.107	0.027
IA2	0.159	**0.869**	0.171	0.186
IA3	0.177	**0.863**	0.174	0.163
IS1	0.223	0.200	**0.747**	0.299
IS2	0.265	0.173	**0.804**	0.181
IS3	0.224	0.099	**0.692**	0.339
IS4	0.339	0.163	**0.637**	0.255
DL1	0.346	0.181	0.296	**0.744**
DL2	0.314	0.124	0.319	**0.798**
DL3	0.331	0.130	0.285	**0.837**
DL4	0.375	0.135	0.288	**0.799**

Bold values are the key values in the analysis.

Data were collected through the online questionnaire platform Wenjuanxing (https://www.wjx.cn/). The response to each item was on a 5-point Likert scale, ranging from 1 to 5 on a scale of strongly disagreeing to strongly agreeing. The Cronbach's α coefficient of each subscale was greater than 0.8, and the average variance explained (AVE) of each construct was greater than 0.5, indicating that each item had acceptable reliability and validity. All the constructs and items were shown in Table 1.

Data collection. Participants were K–12 rural and urban teachers from kindergartens, primary schools, secondary schools, high schools, and vocational schools in Zhejiang province, China. The teachers participated in the implementation training of the Information Technology Application Competence Improvement Project 2.0, which was a large-scale training covering rural and urban areas aimed at improving the teachers' digital teaching competence. The online questionnaires were completed voluntarily and anonymously. Finally, we collected 11,784 valid questionnaires. Table 2 listed the participants' detailed demographic information. In the previous study, geographic locations were divided into two levels, including rural and urban areas (Wu et al. 2023; Thomä, 2023), depending on the remoteness and administrative division of schools. Rural teachers accounted for 43.40% and urban teachers for 56.60%.

Results

Measurement model testing. Principal component analysis was used to test the convergent validity and discriminant validity of each construct. The Kaiser-Meyer-Olkin statistic was 0.942, and the *p*-value of Bartlett's test was less than 0.05, which was strong evidence that the data were suitable for factor analysis (Kaiser, 1974). Four constructs, which explained 81.781% of the total variance, were extracted. Table 3 displayed the rotation factor loads for each item. The factor loads of each construct and its items were above 0.5. In addition, the factor load of each construct and other items was less than 0.5, illustrating accepted convergent validity and discriminant validity (Chin, 1998). Subsequently, AMOS 24 was used for a confirmatory factor analysis.

Table 4 Fit indices of the measurement model.

Fit Indices	RMSEA	NFI	TLI	CFI	IFI
Recommended Value	<0.08	>0.90	>0.90	>0.90	>0.90
Model Value	0.077	0.963	0.955	0.963	0.963

Table 5 Reliability and validity.

Construct	Items	Loadings	AVE	CR	Cronbach's α
Digital teaching competence	DTC1	0.928	0.8542	0.967	0.967
	DTC2	0.938			
	DTC3	0.925			
	DTC4	0.918			
	DTC5	0.912			
ICT attitude	IA1	0.740	0.7178	0.8833	0.879
	IA2	0.903			
	IA3	0.889			
ICT skills	IS1	0.806	0.5873	0.8503	0.844
	IS2	0.797			
	IS3	0.736			
	IS4	0.723			
Data literacy	DL1	0.844	0.816	0.9465	0.946
	DL2	0.894			
	DL3	0.943			
	DL4	0.929			

Since CMIN/DF was easily affected by sample size, the measurement model could be proven from other fit indices (Hu and Bentler, 1998). The results indicated that the fitness of measurement models was acceptable compared to the criteria (Hu and Bentler, 1999), as shown in Table 4. Cronbach's α coefficients, combinatorial reliability (CR), and AVE were calculated to assess construct reliability, convergent validity, and discriminant validity. In Table 5, the CR and Cronbach's α coefficients of each item were above 0.85, indicating good construct reliability (Nunnelly, 1975). Meanwhile, the AVE of each construct was above 0.5, and the loadings of each construct and its item were greater than 0.7, indicating that the convergence validity was also accepted (Fornell and Larcker, 1981). Furthermore, the square root AVEs of each construct were greater than its correlation coefficient with other constructs, and had good discriminating validity, as shown in Table 6 (Fornell and Larcker, 1981).

Hypotheses testing. We proceeded to test the hypotheses after ensuring the reliability and validity of each hypothesis. First, we applied the structural equation model (SEM) in AMOS 24 to examine how teachers' digital teaching competence was affected by ICT attitude, ICT skills, and data literacy (i.e., H1, H3, H5). Then, based on ANOVA in SPSS, we tested hypotheses (i.e., H2, H4, H6, H7) regarding the differences in ICT attitude, ICT skills, data literacy and digital teaching competence between rural and urban teachers.

Structural model testing. The structural model was analyzed by maximum likelihood estimation (MLE) in AMOS 24. As shown in Table 7, each indicator's recommended value was matched by the structural model's fitting indices, indicating an acceptable standard of model fitting. Figure 1 summarized the results of SEM. The overall model had good prediction accuracy, with an explained variance (R2) of 60.3% for digital teaching competence. Regarding the importance of the hypotheses, ICT attitude significantly improved digital teaching competence ($b = 0.152$, $p < 0.001$), supporting H1. ICT skills significantly improved digital teaching competence ($b = 0.378$, $p < 0.001$), supporting H3. Data literacy significantly improved digital teaching competence ($b = 0.374$, $p < 0.001$), supporting H5. The results of hypothesis testing were summarized in Fig. 1.

Table 6 Discriminant validity.

	Digital teaching competence	ICT attitude	ICT skills	Data literacy
DTC	**0.924**	0.447	0.715	0.735
IA		**0.847**	0.506	0.425
IS			**0.766**	0.762
DL				**0.903**

Bold values are the key values in the analysis.

Table 7 Fit indices of the structural model.

Fit Indices	RMSEA	NFI	TLI	CFI	IFI
Recommended Value	<0.08	>0.90	>0.90	>0.90	>0.90
Model Value	0.077	0.963	0.955	0.963	0.963

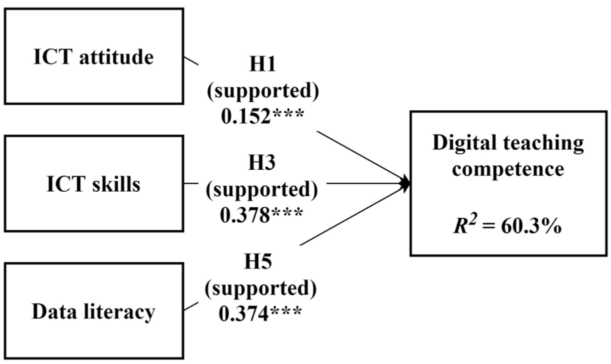

Fig. 1 Research model. Notes: ***$p < 0.001$.

Table 8 ANOVA results for group differences.

	Means		*F value*	*Sig.*	Hypothesis support
	Urban	Rural			
ICT attitude	4.542	4.509	8.158	0.004**	H2 Supported
ICT skills	3.803	3.692	61.847	0.000***	H4 Supported
Data literacy	3.716	3.601	50.082	0.000***	H6 Supported
Digital teaching competence	3.896	3.779	65.528	0.000***	H7 Supported

Notes: ***$p < 0.001$, **$p < 0.01$.

ANOVA testing. ANOVA was used to test hypotheses regarding differences in ICT attitude, ICT skills, data literacy and digital teaching competence between rural and urban teachers. We included means of ICT attitude, ICT skills, data literacy and digital teaching competence as dependent variables and the geographical location of teachers (i.e., rural vs. urban) as independent variables (Hsieh et al. 2011). The results of the variance analysis were shown in Table 8, Fig. 2 and Fig. 3. There were significant differences in ICT attitude, ICT skills, data literacy and digital teaching competence between rural and urban teachers, thus supporting H2, H4, H6, and H7.

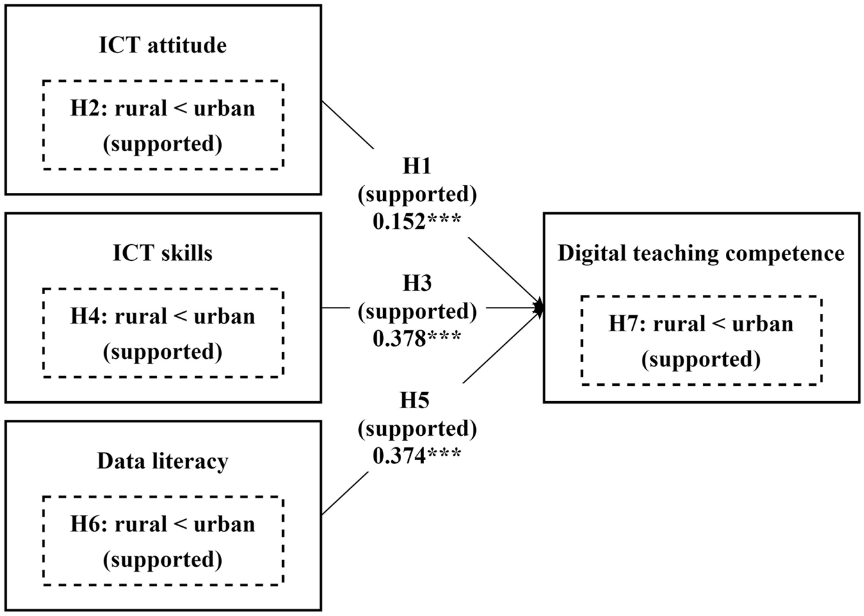

Fig. 2 Summary of results with rural and urban differences. Notes: ***$p < 0.001$.

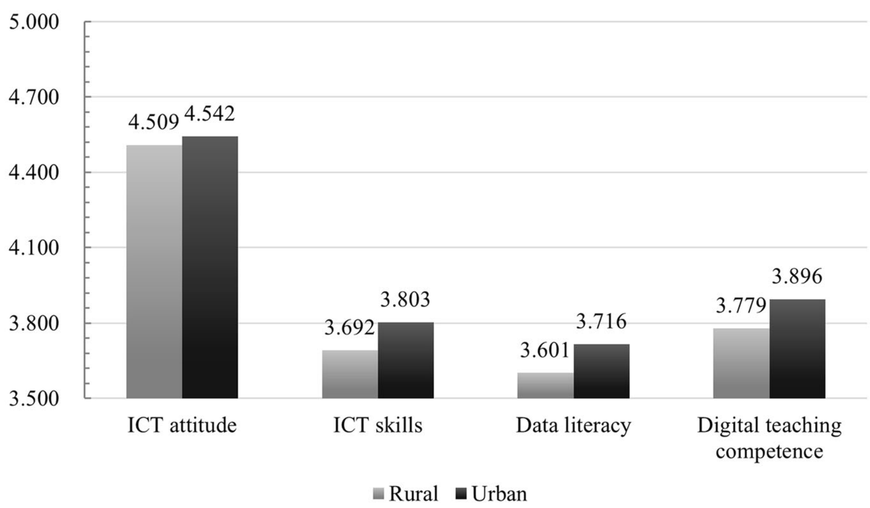

Fig. 3 Detailed comparison for rural and urban teachers.

Decomposition of the divide in digital teaching competence. After the impact of ICT attitude, ICT skills, and data literacy on teachers' digital teaching competence and the existence of a digital divide had been identified, it was imperative to examine the relative significance of the determinants for mitigating the digital divide in digital teaching competence. To determine the extent to which ICT attitude, ICT skills, and data literacy contributed to disparities between rural and urban teachers, we adopted the Blinder-Oaxaca decomposition method, which was appropriate for examining differences between groups. Some researchers applied the Blinder-Oaxaca decomposition method to investigate the salary gap between genders (Bar-Haim et al. 2023), health and medical gap between rural and urban areas (Anyatonwu and San Sebastiá 2022), the transportation-related attitudes difference among generations (Etezady et al. 2021), and the digital divide between races (Fairlie, 2004), etc. For example, Zhao et al. (2017) combined the analysis method to observe the differences in some characteristics, such as education level, and parent-teacher interactions, that affected the cognitive abilities of rural and urban students, then explained the shrinking potential pathways to narrow the gap. Basically, the Blinder-Oaxaca decomposition method mainly explained the difference in the means of the two sets of dependent variables by decomposing the linear regression model.

According to this method, the ordinary least squares (OLS) equations of the difference between rural and urban teachers were expressed as follows:

$$Y_{r,i} = X_i'\beta_r + \varepsilon_{r,i} \tag{1}$$

$$Y_{u,j} = X_j'\beta_u + \varepsilon_{u,j} \tag{2}$$

Among them, $Y_{r,i}$ and $Y_{u,j}$ were the digital teaching competence of rural teacher i and urban teacher j; X was the vector of independent variables and control variables in the Hypotheses model; β_r and β_u were the regression estimation coefficients of rural and urban teachers, respectively; $\varepsilon_{r,i}$ and $\varepsilon_{u,j}$ were random error terms. Therefore, the difference in the digital

Table 9 Blinder-Oaxaca decomposition results.

	Coefficient	Bootstrap Std. Err.	P>|z|	Contribution
Rural	3.779***	0.009	0.000	
Urban	3.895***	0.011	0.000	
Differences	0.116***	0.014	0.000	100.0%
Characteristics Effect	0.092***	0.011	0.000	79.3%
Association Effect	0.024***	0.009	0.011	20.7%

Note: ***indicate the significance at the 0.1% levels, respectively; Bootstrapped standard errors with 500 replications are reported.

Table 10 Detailed decomposition results of the characteristics effect.

	Coefficient	Bootstrap Std. Err.	P > |z|	Contribution
IA	0.004***	0.002	0.009	3.45%
IS	0.031***	0.004	0.000	25.86%
DL	0.050***	0.007	0.000	43.10%
Gender	0.007***	0.001	0.000	6.03%
Years of teaching experience	0.001	0.001	0.011	0.86%

Note: *IA* ICT attitude, *IS* ICT skills, *DL* data literacy; *** indicate the significance at the 0.1% levels, respectively; Bootstrapped standard errors with 500 replications are reported.

teaching competence of rural and urban teachers was expressed as follows:

$$\overline{Y}_r - \overline{Y}_u = \left[\underbrace{\left[\widehat{\beta}_r(\overline{X}_r - \overline{X}_u)\right]}_{\textit{characteristics effect}} + \underbrace{\left[\widehat{X}_u\left(\widehat{\beta}_r - \widehat{\beta}_u\right)\right]}_{\textit{association effect}} \right] \tag{3}$$

As shown in Eq. (3), $\overline{Y}_r - \overline{Y}_u$ represented the observed difference in the average level of digital teaching competence between rural and urban teachers, $\widehat{\beta}_r$ and $\widehat{\beta}_u$ was a vector of regression estimation coefficients for Eqs. (1) and (2). $\overline{X}_r$ and $\overline{X}_u$ were the vectors of the characteristics mean of rural and urban teachers. The difference in digital teaching competence could be decomposed into two aspects: characteristic effect and association effect. The first term $\widehat{\beta}_r(\overline{X}_r - \overline{X}_u)$ represented the inter-group characteristic effect caused by the difference. Specifically, the characteristic effect, e.g., ICT attitude, ICT skills, data literacy, gender, and years of teaching experience, was due to the different digital teaching competence of rural and urban teachers. The second term $\overline{X}_u\left(\widehat{\beta}_r - \widehat{\beta}_u\right)$ indicated that the association effect captured the inconsistency in the digital teaching competence of rural and urban teachers, owing to the regression estimation of the differences in the coefficients in Eqs. (1) and (2). The association effect captured all the potential effects of differences in unobservable characteristics.

We performed Blinder-Oaxaca decomposition method in Stata 15. The results were shown in Table 9. The results showed that urban teachers were 0.116 points more competent in digital teaching than rural teachers. On the one hand, the characteristics effect represented different levels of observed factors, including ICT attitude, ICT skills, data literacy, and other control variables, accounting for 79.3% (0.092 / 0.116 = 79.3%) of the rural-urban numerical gap. On the other hand, the association effect due to the difference between rural and urban teachers in the unobserved part accounted for 20.7%.

Next, to determine the relative importance of the influencing factors, we analyzed the detailed characteristic effects and presented the decomposition results of each observed factor. Table 10 displayed the contributions made by each factor to the explanation of rural and urban teachers' digital teaching competence, indicating the relative importance of each factor in explaining the difference in digital teaching competence between the rural and urban teachers. To be specific, data literacy and ICT skills were the most important factors affecting the difference in digital teaching competence. They explained 43.10 and 25.86% of the variance in the numerical results, respectively.

Discussion

What are the potential factors that influence teachers' digital teaching competence? As Fig. 1 was shown, the study built and analyzed a structural equation model, which revealed that ICT attitude, ICT skills, and data literacy had significant positive correlations on digital teaching competence. Previous studies constructed models, confirming some factors influencing teachers' digital teaching competence, such as attitude (Scherer et al. 2019; Huang and Liaw, 2005), skills (Guillén-Gámez et al. 2023; Kaarakainen et al. 2018; Knezek and Christensen, 2016), gender, age (He et al. 2023) and so on. Therefore, we focused on exploring the endogenous factors, including attitude and skills, combined with data literacy, which is rarely explored in prior studies but proven to be necessary for teachers. First, we showed that the positive impact of ICT attitude on digital teaching competence (supported H1), which was consistent with some previous studies (Antonietti et al. 2022; Hernández-Ramos et al. 2014). For example, Latorre-Cosculluela et al. (2023) investigated 345 university teachers and found that teachers' ICT attitude had a direct impact on digital teaching behaviors. However, some researchers found that ICT attitude was no significant impact on digital teaching competence (Wang and Zhao, 2021; Ndibalema, 2014). For example, Lin et al. (2022), who focused on urban teachers, confirmed that ICT attitude were mediated by ICT skills but not directly significant to influence digital teaching competence. The differences in research model and characteristics of the participants might account for the inconsistent in the conclusions. In this article, we investigated the groups including both rural and urban teachers and found the important role in teachers' digital teaching competence. Second, ICT skills had a significant impact on digital teaching competence (supported H3). Hatlevik (2017) also discovered that ICT skills predicted changes in teachers' digital competence. This evidence showed the role of ICT skills in teachers with higher digital teaching competence (Hämäläinen et al. 2021; Hatlevik, 2017). Third, we confirmed data literacy was also significantly correlated with teachers' digital teaching competence (supported H5), which was underestimated in the prior studies. As previous studies proposed, teachers' use of data in the classroom could improve their teaching (Coburn and Turner, 2011). Therefore, providing an authentic experience of data literacy with teachers was the one of effective measure to enhance digital teaching competence. All in all, the above findings provided new insights for how to promote teachers' digital teaching competence.

Does the divide in digital teaching competence exist between rural and urban teachers? This study revealed that the digital divide existed. Specifically, we found that the ICT attitude, ICT skills, data literacy, and digital teaching competence of rural teachers were significantly lower than those of urban teachers, shown in Fig. 2, which confirmed concerns about the competence divide implicit in SDG 4 and recent research (United Nations, 2022; Thannimalai et al. 2022). First, ICT attitude of rural teachers was lower than that of urban teachers. Teachers' own ICT attitude and perceptions were proven to be one of the endogenous motivations influencing the digital divide, more important than the exogenous motivation, such as availability of material resources (Soomro et al. 2020). In addition, this study revealed that the average of both rural and urban teachers in ICT attitude was greater than 4.5, which mean that both rural and urban teachers had a high level of ICT attitude. It can be explained that teachers were no longer resisting ICT in teaching. In recent years, more and more ICT initiatives about digital transformation were developed and implemented at the national level in China, such as the Pilot Work of Artificial Intelligence to Promote Teacher Team Construction, the Action Plan for the Revitalization of Teacher Education (2018–2022), and so on. As we can see, developing ICT initiatives was effective in encouraging teachers to accept the use of ICT (Chen et al. 2022; Jackman et al. 2021; Wu et al. 2019), and the attitude gap between rural and urban teachers towards ICT was gradually bridged. Second, we found that rural teachers had lower ICT skills and data literacy than urban teachers, which pointed to ICT skills and data literacy gap between rural and urban teachers. Due to the late introduction of ICT infrastructure and data use in rural schools (Wang and Zhao, 2021), teachers were exposed to the environment of digital technology and data in a shorter time. Differentiated ICT skills and data use may exacerbate existing competence stratification, leading to a widening digital divide between the rural and urban teachers. Therefore, rural teachers needed time and training to improve their skills for making full use of data. Third, there was a divide in digital teaching competence, indicating that rural teachers were poor at possessing the technical, pedagogical, and didactic incorporation of digital technologies in education (Cabero-Almenara et al. 2021). Chen et al. (2023) also determined the significant differences in the application of digital technology among rural, county, and urban schools. As Yu et al. (2023) found, urban teachers were better equipped to fully integrate digital technologies into education, which indicated that rural teachers were facing the problem of difficult integration of digital technology and teaching. To conclude, these findings above confirmed that there was indeed a second-order digital divide between rural and urban teachers, but the relative importance of determinants to the digital divide needed to be further explored.

What is the relative importance of the different factors contributing to the competence divide? In order to further discover the underlying determinants that might lead to the inequality of digital teaching competence between rural and urban teachers, the Blinder-Oaxaca decomposition method was adopted. The characteristics effects presented that the differences in ICT attitude, ICT skills, data literacy, gender, and years of teaching experience between rural and urban teachers accounted for 79.3% of the divide in digital teaching competence, as shown in Table 9. The above analysis signified that the 79.3% divide would be reduced, if rural and urban teachers had the same level of ICT attitude, ICT skills, data literacy, gender and years of teaching experience, which was extremely important for mitigating the digital divide. To be more specific, Table 10 showed the contribution of each observed factor to the overall digital divide of teachers in rural and urban areas. Data literacy and ICT skills were two key factors contributing to the divide in digital teaching competence, which explained the gap of 43.10 and 25.86%, respectively. These results revealed that data literacy and ICT skills were important determinants of reducing the digital teaching competence gap between rural and urban teachers. How to improve teachers' data literacy and ICT skills remained a key issue.

As education went digital, schools tended to become more networked and data-driven. Previous research confirmed that data already constituted an integral element in students' learning (Gouseti et al. 2023; Conn et al. 2022), and data literacy became a necessary skill for teachers in making decisions about student progress (Trantham et al. 2021). However, we found that data literacy was the lowest among several factors for both rural and urban teachers, which was a less prominent determinant for teachers (Gouseti et al. 2023). Existing research reported that teachers had few curricula to prepare for data literacy, and they lacked confidence in their data literacy and using data to assist teaching effectively (Shreiner and Guzdial, 2022). In this context, there was an urgent need to enrich teachers' data literacy (Marín et al. 2021), especially in rural areas, so that teachers should undergo training to equip themselves. What's more, data literacy, which should cover both technical and pedagogical features, needed to be integrated into the framework for teachers' professional development (Conn et al. 2022; Cui and Zhang, 2022). At the region-wide level, further investment in teacher training programs needed to be encouraged to help teachers integrate data to improve their teaching practices, particularly with regard to rural teachers. Teachers should gradually learn to make full use of data, such as students' attendance, academic performance, interest, and so on, from the whole process of data collection, data analysis, data evaluation, and data application to optimize daily teaching. Teachers' teaching decisions were no longer determined by a single subjective experience, making teachers' teaching decisions more scientific and effective, benefiting from data.

Regarding ICT skills, our study found that ICT skills had a greater impact on the divide in teachers' digital teaching competence. As we can see, the ICT skills of rural teachers still needed to be improved. Although the construction of ICT infrastructure (including networks, hardware, and resources) in rural areas was gradually equipped in China. In fact, few teachers used teaching tools or digital resources as teaching necessities and integrate them into their teaching. What's more, some teachers with poor competence felt that the use of digital technologies would burden their teaching. The above situation created a vicious circle in which the less teachers did apply technology, the more they lacked the ICT skills to use technologies, and their digital teaching competence could not be improved. If rural teachers did not use the technologies, ICT infrastructures would become idle, and bridging the first-order digital divide, that is, building ICT infrastructures, would be wasted. (Wu et al. 2022; Li et al. 2020; Wang et al. 2019). As proposed by the World Bank, if you're going to invest in technology, invest in the training, support, monitoring, and maintenance to make it work (David, 2021). Therefore, the most imperative initiative was to strengthen ICT training and support for rural teachers, which needed to be supported and guaranteed by relevant government departments. In addition, rural school leaders needed to raise awareness to encourage teachers to integrate technology into their work and teaching and to form a school-level digital culture by organizing related activities for teachers to co-innovate teaching, such as competitions, educational research, and so on.

Conclusion, implication, and limitation

This study contributed to the research on bridging the digital divide by providing evidence on the difference in digital teaching competence between rural and urban teachers. Through investigating 11,784 rural and urban teachers who participated in the survey studies, this study firstly found positive effects between ICT attitude, ICT skills, and data literacy on digital teaching competence. In addition, there was a digital divide between rural and urban teachers in the four factors listed above, of which data literacy and ICT skills were key determinants of rural-urban divide in teachers' digital teaching competence. In consequence, this study expanded the scope of research that contributes to the digital divide and provided empirical evidence for some unexplored determinants in digital teaching competence between rural and urban teachers. To the best of our knowledge, few studies discovered that the determinants contributed to the divide between rural and urban teachers' digital teaching competence.

Based on the empirical results, practice implications can be made from both macro perspectives for policymakers and school leaders, and micro perspectives for teachers, particularly rural teachers. From macro perspectives, firstly, policymakers and school leaders need to move beyond the narrow views that the digital divide is merely poverty and a lack of ICT infrastructure. What's more, the digital divide also refers to the difference in digital teaching competence between rural and urban teachers. Second, after recognizing the digital competence divide between rural and urban teachers, intervention plans should be designed, especially for rural teachers, such as developing policies, providing teacher training, and initiating mutual aid activities between rural and urban teachers to promote exchanging and sharing their digital teaching experience. Prior studies proved that, in rural schools, weak communication and interaction between teachers would negatively impact teachers' use of digital technologies (Galanouli et al. 2004). Third, teachers' data literacy, ICT skills, and other factors should be integrated into the teacher training framework to alleviate the digital competence divide and promote balanced education development. From micro perspectives, according to ICT skills, teachers need to be proficient in using digital equipment, web platforms, artificial intelligence tools, and skilled in solving common problems with digital teaching that arise at any time in the classroom. About data literacy, teachers need to be proficient in retrieving data, analyzing data, judging data, and making teaching decisions. Last but not least, teachers should master the digital teaching competence to support the whole teaching session, from preparing digital media and resource, innovating pedagogy, integrating technology into teaching, providing targeted recommendations, and providing technical support for students.

Although some meaningful findings were proposed, the current study also had some limitations. First, our survey focused on one province in China, which was not broad enough. Second, the research findings might apply to regions where ICT infrastructures were generally developed. Notably, for other countries or regions with poor Internet access or hardware, it might be more urgent and practical to pay attention to building ICT infrastructures to bridge the first-order digital divide (Zhao et al. 2022). Third, this study highlighted that the digital divide existed, which was likely to persist in the future. After further bridging the digital competence divide between teachers and students, the third-order digital divide, that is, the digital outcome divide, can be further explored.

Data availability

All data generated or analyzed during this study are included in this published article and its supplementary file.

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References

Aissaoui N (2022) The digital divide: a literature review and some directions for future research in light of COVID-19. Glob Knowl Mem Commun 71(8/9):686–708. https://doi.org/10.1108/GKMC-06-2020-0075

Antonietti C, Cattaneo A, Amenduni F (2022) Can teachers' digital competence influence technology acceptance in vocational education? Comput Hum Behav 132:107266. https://doi.org/10.1016/j.chb.2022.107266

Anyatonwu OP, San Sebastián M (2022) Rural-urban disparities in postpartum contraceptive use among women in Nigeria: A Blinder-Oaxaca decomposition analysis. Int J Equity Health 21(1):71. https://doi.org/10.1186/s12939-022-01674-9

Aslan A, Zhu C (2017) Investigating variables predicting Turkish pre-service teachers' integration of ICT into teaching practices. Br J Educ Technol 48(2):552–570. https://doi.org/10.1111/bjet.12437

Aydin M (2022) A multilevel modeling approach to investigating factors impacting computer and information literacy: ICILS Korea and Finland sample. Educ Inf Technol 27(2):1675–1703. https://doi.org/10.1007/s10639-021-10690-1

Bar-Haim E, Chauvel L, Gornick JC et al. (2023) The Persistence of the Gender Earnings Gap: Cohort Trends and the Role of Education in Twelve Countries. Soc Indic Res 165(3):821–841. https://doi.org/10.1007/s11205-022-03029-x

Ben Youssef A, Dahmani M, Ragni L (2022) ICT use, digital skills and students' academic performance: Exploring the digital divide. Information 13(3):129. https://doi.org/10.3390/info13030129

Cabero-Almenara J, Barroso-Osuna J, Gutiérrez-Castillo et al. (2021) The teaching digital competence of Health Sciences teachers. A study at Andalusian Universities. Int J Environ Res Public Health 18(5):2552. https://doi.org/10.3390/ijerph18052552

Califf CB, Brooks S (2020) An empirical study of techno-stressors, literacy facilitation, burnout, and turnover intention as experienced by K-12 teachers. Compu Educ 157:103971. https://doi.org/10.1016/j.compedu.2020.103971

Castaño Muñoz J, Pokropek A, Weikert García L (2022) For to all those who have, will more be given? Evidence from the adoption of the SELFIE tool for the digital capacity of schools in Spain. Br J Educ Technol 53(6):1937–1955. https://doi.org/10.1111/bjet.13222

Chen M, Zhou C, Man S, Li Y (2023) Investigating teachers' information literacy and its differences in individuals and schools: A large-scale evaluation in China. Educ Inf Technol 28(3):3145–3172. https://doi.org/10.1007/s10639-022-11271-6

Chen M, Zhou C, Wang Y et al. (2022) The role of school ICT construction and teacher information literacy in reducing teacher burnout: Based on SEM and fsQCA. Educ Inf Technol 27(6):8751–8770. https://doi.org/10.1007/s10639-022-10989-7

Chin WW (1998) Commentary: Issues and opinion on structural equation modeling. MIS quarterly, vii-xvi

Coburn CE, Turner EO (2011) Research on Data Use: A Framework and Analysis. Measurement: Interdiscip Res and Perspectives 9(4):173–206. https://doi.org/10.1080/15366367.2011.626729

Colicol FL, Colicol-Rodriguez EL (2023) Urban-rural divide and COVID-19: engaging teachers to assess and improve the Philippine basic education-learning continuity plan. Asia Pac J Educ 1–16. https://doi.org/10.1080/02188791.2023.2195099

Conn CA, Bohan KJ, Bies-Hernandez N et al. (2022) Expected data literacy knowledge and skills for early career teachers: Perspectives from school and district personnel. Teach Teach Educ 111:103607. https://doi.org/10.1016/j.tate.2021.103607

Corkin MT, Meissel K, Peterson ER et al. (2022) Are distinct modes of using digital technologies evident by age eight? Implications for digital divides. Comput Educ 191:104642. https://doi.org/10.1016/j.compedu.2022.104642

Creighton TB (2018) Digital natives, digital immigrants, digital learners: An international empirical integrative review of the literature. Educ Leadersh Rev 19(1):132–140

Cui Y, Zhang H (2021) Educational neuroscience training for teachers' technological pedagogical content knowledge construction. Front Psychol 12:792723. https://doi.org/10.3389/fpsyg.2021.792723

Cui Y, Zhang H (2022) Integrating teacher data literacy with TPACK: A self-report study based on a novel framework for teachers' professional development. Front Psychol 13:966575. https://doi.org/10.3389/fpsyg.2022.966575

Cui Y, Chen F, Lutsyk A et al. (2023) Data literacy assessments: A systematic literature review. Assess Educ 30(1):76–96. https://doi.org/10.1080/0969594X.2023.2182737

Dauvarte L (2015) Teacher's ICT competence in home economics and technologies lessons. Rural Environ Educ Pers 15:89–100

David KE (2021) Education Technology for Effective Teachers. https://documents1.worldbank.org/curated/en/216711611954778027/pdf/Education-Technology-for-Effective-Teachers.pdf. Accessed 28 Mar 2023

Dolan J (2016) Splicing the divide: A review of research on the evolving digital divide among k-12 students. J Res Technol Educ 48(1):16–37. https://doi.org/10.1080/15391523.2015.110314736

Drent M, Meelissen M (2008) Which factors obstruct or stimulate teacher educators to use ICT innovatively. Comput Educ 51(1):187–199. https://doi.org/10.1016/j.compedu.2007.05.001
ElSayary A (2023) The impact of a professional upskilling training programme on developing teachers' digital competence. J Comput Assist Learn. https://doi.org/10.1111/jcal.12788
Estanyol E, Montaña M, Fernández-de-Castro P et al. (2023) Digital competence among young people in Spain: A gender divide analysis. Comunicar 31(74):113–123
Etezady A, Shaw FA, Mokhtarian PL et al. (2021) What drives the gap? Applying the Blinder–Oaxaca decomposition method to examine generational differences in transportation-related attitudes. Transportation 48:857–883. https://doi.org/10.1007/s11116-020-10080-5
Fairlie RW (2004) Race and the Digital Divide. Contrib Eco Anal Policy 3(1):1–38. https://doi.org/10.2202/1538-0645.1263
Fornell C, Larcker DF (1981) Evaluating structural equation models with unobservable variables and measurement error. J Mark Res 18(1):39–50. https://doi.org/10.1177/002224378101800104
Gabr HM, Soliman SS, Allam HK et al. (2021) Effects of remote virtual work environment during COVID-19 pandemic on technostress among Menoufia University Staff, Egypt: A cross-sectional study. Environ Sci Pollut Res 28(38):53746–53753. https://doi.org/10.1007/s11356-021-14588-w
Galanouli D, Murphy C, Gardner J (2004) Teachers' perceptions of the effectiveness of ICT-competence training. Comput Educ 43(1):63–79. https://doi.org/10.1016/j.compedu.2003.12.005
Gebre E (2022) Conceptions and perspectives of data literacy in secondary education. Br J Educ Technol 53(5):1080–1095. https://doi.org/10.1111/bjet.13246
Goudeau S, Sanrey C, Stanczak A et al. (2021) Why lockdown and distance learning during the COVID-19 pandemic are likely to increase the social class achievement gap. Nat Hum Behav 5(10):1273–1281. https://doi.org/10.1038/s41562-021-01212-7
Gouseti A, Lakkala M, Raffaghelli J et al. (2023) Exploring teachers' perceptions of critical digital literacies and how these are manifested in their teaching practices. Educ Rev 1–35. https://doi.org/10.1080/00131911.2022.2159933
Gudmundsdottir GB, Hatlevik OE (2018) Newly qualified teachers' professional digital competence: Implications for teacher education. Eur. J Teach Educ 41(2):214–231. https://doi.org/10.1080/02619768.2017.1416085
Guillén-Gámez FD, Ruiz-Palmero J, García MG (2023) Digital competence of teachers in the use of ICT for research work: development of an instrument from a PLS-SEM approach. Educ Inf Technol 1–21. https://doi.org/10.1007/s10639-023-11895-2
Gummer E, Mandinach E (2015) Building a conceptual framework for data literacy. Teach Coll Rec 117(4):1–22. https://doi.org/10.1177/016146811511700401
Gupta D, Singh G (2018) Competency of Teacher Educators and Student Teachers towards E-learning Tools. the NCERT and no matter may be reproduced in any form without the prior permission of the NCERT 44(2):126
Hämäläinen R, Nissinen K, Mannonen J et al. (2021) Understanding teaching professionals' digital competence: What do PIAAC and TALIS reveal about technology-related skills, attitudes, and knowledge? Comput Hum Behav 117:106672. https://doi.org/10.1016/j.chb.2020.106672
Hatlevik OE (2017) Examining the relationship between teachers' self-efficacy, their digital competence, strategies to evaluate information, and use of ICT at school. Scand J Educ Res 61(5):555–567. https://doi.org/10.1080/00313831.2016.1172501
He Z, Chen X, Guo S (2023) Digital competence and its components in basic education. Interact Learn Environ 1–12. https://doi.org/10.1080/10494820.2023.2211636
Hernández-Ramos JP, Martínez-Abad F, García Peñalvo FJ et al. (2014) Teachers' attitude regarding the use of ICT. A factor reliability and validity study. Comput Hum Behav 31:509–516. https://doi.org/10.1016/j.chb.2013.04.039
Hsieh JJPA, Rai A et al. (2011) Addressing digital inequality for the socioeconomically disadvantaged through government initiatives: Forms of capital that affect ICT utilization. Inf Syst Res 22(2):233–253. https://doi.org/10.1287/isre.1090.0256
Hu L, Bentler PM (1998) Fit indices in covariance structure modeling: Sensitivity to under parameterized model misspecification. Psychol Methods 3(4):424. https://doi.org/10.1037/1082-989X.3.4.424
Hu L, Bentler PM (1999) Cut of criteria for ft indexes in covariance structure analysis: Conventional criteria versus new alternatives. Struct Equ Modeling 6(1):1–55. https://doi.org/10.1080/10705519909540118
Huang HM, Liaw SS (2005) Exploring users' attitudes and intentions toward the web as a survey tool. Comput Hum Behav 21(5):729–743. https://doi.org/10.1016/j.chb.2004.02.020
Ilomäki L, Paavola S, Lakkala M et al. (2016) Digital competence – an emergent boundary concept for policy and educational research. Educ Inf Technol 21:655–679. https://doi.org/10.1007/s10639-014-9346-4
Jackman JA, Gentile DA, Cho NJ et al. (2021) Addressing the digital skills gap for future education. Nat Hum Behav 5(5):542–545. https://doi.org/10.1038/s41562-021-01074-z
Kaarakainen MT, Kivinen O, Vainio T (2018) Performance-based testing for ICT skills assessing: A case study of students and teachers' ICT skills in Finnish schools. Univers Access Inf Soc 17:349–360. https://doi.org/10.1007/s10209-017-0553-9
Kaiser HF (1974) An index of factorial simplicity. Psychometrika 39(1):31–36. https://doi.org/10.1007/BF02291575
Kennedy-Clark S, Reimann P (2022) Knowledge types in initial teacher education: a multi-dimensional approach to developing data literacy and data fluency. Res Pract 8(1):42–58. https://doi.org/10.1080/23735082.2021.1957140
Keramati A, Afshari-Mofrad M, Kamrani A (2011) The role of readiness factors in E-learning outcomes: An empirical study. Comput Educ 57(3):1919–1929. https://doi.org/10.1016/j.compedu.2011.04.005
Khairani AZ (2017) Assessing urban and rural teachers' competencies in STEM integrated education in Malaysia. MATEC Web of Conferences. https://doi.org/10.1051/matecconf/20178704004
Knezek G, Christensen R (2016) Extending the will, skill, tool model of technology integration: Adding pedagogy as a new model construct. J Comput High Educ 28(3):307–325. https://doi.org/10.1007/s12528-016-9120-2
Latorre-Cosculluela C, Sierra-Sánchez V, Rivera-Torres P et al. (2023) ICT efficacy and response to different needs in university classrooms: Effects on attitudes and active behavior towards technology. J Comput High Educ 1–18. https://doi.org/10.1007/s12528-023-09357-2
Le TV, Galperin H, Traube D (2023) The Impact of Digital Competence on Telehealth Utilization. Health Policy Technol 100724. https://doi.org/10.1016/j.hlpt.2023.100724
Li G, Zhang X, Liu D et al. (2023) Education and EdTech during COVID-19: Evidence from a Large-Scale Survey during School Closures in China. Comp Educ Rev 67(1):53–77. https://doi.org/10.1086/723027
Li J, Shi Z, Xue E (2020) The problems, needs and strategies of rural teacher development at deep poverty areas in China: Rural schooling stakeholder perspectives. Int J Educ Res 99:101496. https://doi.org/10.1016/j.ijer.2019.101496
Liao PA, Chang HH, Wang JH et al. (2016) What are the determinants of rural-urban digital inequality among schoolchildren in Taiwan? Insights from Blinder-Oaxaca decomposition. Comput Educ 95:123–133. https://doi.org/10.1016/j.compedu.2016.01.002
Lin R, Yang J, Jiang F et al. (2022) Does teacher's data literacy and digital teaching competence influence empowering students in the classroom? Evidence from China. Educ Inf Technol 28(3):2845–2867. https://doi.org/10.1007/s10639-022-11274-3
Liu S, Teddlie C (2009) Case studies of educational effectiveness in rural China. J Educ Students Placed Risk 14(4):334–355
Luo H, Zuo M, Wang J (2022a) Promise and reality: Using ICTs to bridge China's rural-urban divide in education. Educ Technol Res Dev 70(3):1125–1147. https://doi.org/10.1007/s11423-022-10118-8
Luo Y, Tack H, Valcke M, et al. (2022b) Unpacking the rural-urban gap of teacher involvement in inquiry-based working: The roles of school research culture and infrastructure. Prof Dev Educ 1–18. https://doi.org/10.1080/19415257.2022.2155985
Lutz C (2019) Digital inequalities in the age of artificial intelligence and big data. Hum Behav Emerging Technol 1:141–148. https://doi.org/10.1002/hbe2.140
Mahdum M, Hadriana H, Safriyanti M (2019) Exploring teacher perceptions and motivations to ICT use in learning activities in Indonesia. J Inf Technol Educ 18. https://doi.org/10.28945/4366
Marín VI, Carpenter JP, Tur G (2021) Pre-service teachers' perceptions of social media data privacy policies. Br J Educ Technol 52(2):519–535. https://doi.org/10.1111/bjet.13035
Mitchell L, Nath J (2013) Developing self-efficacy in an urban education program. Int J of Case Method Res Appl 25(3):160–167
Ndibalema P (2014) Teachers' attitudes towards the use of Information Communication Technology (ICT) as a pedagogical tool in secondary schools in Tanzania: The case of Kondoa district. Int J Educ Res 2(2):1–16
Nunnally JC (1975) Psychometric Theory - 25 Years Ago and Now. Educ Researcher 4(10):7–21. https://doi.org/10.3102/0013189X004010007
Papamitsiou Z, Filippakis ME, Poulou M et al. (2021) Towards an educational data literacy framework: Enhancing the profiles of instructional designers and e-tutors of online and blended courses with new competences. Smart Learn Environ 8(1):1–26. https://doi.org/10.1186/s40561-021-00163-w
Quaicoe JS, Pata K (2020) Teachers' digital literacy and digital activity as digital divide components among basic schools in Ghana. Educ Inf Technol 25:4077–4095. https://doi.org/10.1007/s10639-020-10158-8
Ragnedda M, Ruiu M (2017) Social capital and the three levels of digital divide. https://doi.org/10.4324/9781315455334-3
Rana K, Greenwood J, Fox-Turnbull WH et al. (2018) A Shift from Traditional Pedagogy in Nepali Rural Primary Schools. 14(3):149–166

Salemink K, Strijker D, Bosworth G (2017) Rural development in the digital age: A systematic literature review on unequal ICT availability, adoption, and use in rural areas. J Rural Stud 54:360–371. https://doi.org/10.1016/j.jrurstud.2015.09.001

Sang G, Valcke M, Van BJ et al. (2011) Predicting ICT integration into classroom teaching in Chinese primary schools: exploring the complex interplay of teacher-related variables. J Comput Assist Learn 27(2):160–172. https://doi.org/10.1111/j.1365-2729.2010.00383.x

Scherer R, Siddiq F, Tondeur J (2019) The technology acceptance model (TAM): A meta-analytic structural equation modeling approach to explaining teachers' adoption of digital technology in education. Comput Educ 128:13–35. https://doi.org/10.1016/j.compedu.2018.09.009

Shreiner TL, Guzdial M (2022) The information won't just sink in: Helping teachers provide technology-assisted data literacy instruction in social studies. Br J Educ Technol 53(5):1134–1158. https://doi.org/10.1111/bjet.13255

Simonsson M (2004) Technology Use of Hispanic Bilingual Teachers: A Function of their Beliefs, Attitudes and Perceptions on Peer Technology Use in the Classroom. J Instr Psychol 31(3):257–266

Soomro KA, Kale U, Curtis R et al. (2020) Digital divide among higher education faculty. Int J Educ Technol High Educ 17:1–16. https://doi.org/10.1186/s41239-020-00191-5

Sun J, Przybylski R, Johnson BJ (2016) A review of research on teachers' use of student data: From the perspective of school leadership. Educ Assess Eval Account 28:5–33. https://doi.org/10.1007/s11092-016-9238-9

Thannimalai T, Ponniah K, Nawastheen F et al. (2022) Attitudes and acceptance of information and communication technology (ICT) among urban and rural teachers in teaching and facilitation. Int J Adv Appl Sci 9:16–23. https://doi.org/10.21833/ijaas.2022.07.003

The Word Bank (2022) Ending learning poverty and building skills: investing in education from early childhood to lifelong learning. https://thedocs.worldbank.org/en/doc/7b8e1ecfbeb0507559134a346bd64bc2-0200022022/related/WB-EducationBrochure-OCT-11-22-final-e-version-SP.pdf. Accessed 28 Mar 2023

Thomä J (2023) An urban-rural divide (or not?): Small firm location and the use of digital technologies. J Rural Stud 97:214–223. https://doi.org/10.1016/j.jrurstud.2022.12.020

Tian Y, Liu L, Wang X et al. (2021) Urban-Rural Differences in Physical Fitness and Out-of-School Physical Activity for Primary School Students: A County-Level Comparison in Western China. Int J Environ Res Public Health 18(20):10813. https://doi.org/10.3390/ijerph182010813

Timotheou S, Miliou O, Dimitriadis Y et al. (2022) Impacts of digital technologies on education and factors influencing schools' digital capacity and transformation: A literature review. Int J Educ Inf Technol 1–32. https://doi.org/10.1007/s10639-022-11431-8

Trantham PS, Sikorski J, de Ayala RJ et al. (2021). An item response theory and Rasch analysis of the NUDKS: a data literacy scale. Educ Assess Eval Account 1–23. https://doi.org/10.1007/s11092-021-09372-w

UNESCO (2021) RewirEd Global Declaration on Connectivity for Education. https://en.unesco.org/futuresofeducation/steering-digital-transformation-0. Accessed 20 Mar 2023

United Nations (2022) The Sustainable Development Goals Report 2022. https://unstats.un.org/sdgs/report/2022/. Accessed 20 Mar 2023

van Dijk JAGM (2006) Digital divide research, achievements and shortcomings. Poetics 34(4):221–235. https://doi.org/10.1016/j.poetic.2006.05.004

van Dijk JAGM (2020) Closing the digital divide. The role of digital technologies on social development, well-being of all and the approach of the covid-19 pandemic [white paper]. https://www.un.org/development/desa/dspd/wp-content/uploads/sites/22/2020/07/Closing-the-Digital-Divide-by-Jan-A.G.M-van-Dijk-.pdf. Accessed 22 Mar 2023

Wahyudi, Treagust DF (2004) An investigation of science teaching practices in Indonesian rural secondary schools. Res Sci Educ 34(4):455–474. https://doi.org/10.1007/s11165-004-5165-8

Wang J, Tigelaar DEH, Admiraal W (2019) Connecting rural schools to quality education: Rural teachers' use of digital educational resources. Comput Hum Behav 101(1):68–76. https://doi.org/10.1016/j.chb.2019.07.009

Wang Q, Zhao G (2021) ICT Self-Efficacy Mediates Most Effects of University ICT Support on Preservice Teachers' TPACK: Evidence from Three Normal Universities in China. Br J Educ Technol 52(6):2319–2339. https://doi.org/10.1111/bjet.13141

Wei L, Hindman DB (2011) Does the digital divide matter more? Comparing the effects of new media and old media use on the education-based knowledge gap. Mass Commun Soc 14:216–235. https://doi.org/10.1080/15205431003642707

Weninger C (2022) Skill versus Social Practice? Some Challenges in Teaching Digital Literacy in the University Classroom. Tesol Q 56(3):1016–1028. https://doi.org/10.1002/tesq.3134

Wu B, Yu X, Hu Y (2019) How does principal e-leadership affect ICT transformation across different school stages in K-12 education: Perspectives from teachers in Shanghai. Br J Educ Technol 50(3):1210–1225. https://doi.org/10.1111/bjet.12766

Wu D, Yang X, Yang W et al. (2022) Effects of teacher- and school-level ICT training on teachers' use of digital educational resources in rural schools in China: A multilevel moderation model. Int J Educ Res 111:101910. https://doi.org/10.1016/j.ijer.2021.101910

Wu J, Shen Z, Li Q et al. (2023) How urban versus rural residency relates to COVID-19 vaccine hesitancy: A large-scale national Chinese study. Soc Sci Med 320:115695. https://doi.org/10.1016/j.socscimed.2023.115695

Wu X, Xu T, Zhang Y (2021) Research on the data analysis knowledge assessment of pre-service teachers from China based on cognitive diagnostic assessment. Curr Psychol 1–15. https://doi.org/10.1007/s12144-021-01836-y

Yang HH, Zhu S, MacLeod J (2018) Promoting Education Equity in Rural and Underdeveloped Areas: Cases on Computer-Supported Collaborative Teaching in China. Eur J Mathematics Sci Technol Educ 14(6):2393–2405. https://doi.org/10.29333/ejmste/89841

Yang L, Martínez-Abad F, García-Holgado A (2022) Exploring factors influencing pre-service and in-service teachers´ perception of digital competencies in the Chinese region of Anhui. Educ Inf Technol 1–26. https://doi.org/10.1007/s10639-022-11085-6

Yu L, Wu D, Zhu S et al. (2020) School and Teacher Level Predictors for Students' Information Literacy in Chinese Rural and Urban Education. In Proceedings of the 28th International Conference on Computers in Education

Yuen AH, Ma WW (2008) Exploring teacher acceptance of e-learning technology. Asia-Pac J Teach Educ 36(3):229–243. https://doi.org/10.1080/13598660802232779

Zarifa D, Seward B, Milian RP (2019) Location, location, location: Examining the rural-urban skills gap in Canada. J Rural Stud 72:252–263. https://doi.org/10.1016/j.jrurstud.2019.10.032

Zhao G, Ye J, Li Z et al. (2017) How and why do Chinese urban students outperform their rural counterparts. China Econ Rev 45:103–123. https://doi.org/10.1016/j.chieco.2017.06.006

Zhao L, Cao C, Li Y et al. (2022) Determinants of the digital outcome divide in E-learning between rural and urban students: Empirical evidence from the COVID-19 pandemic based on capital theory. Comput Hum Behav 130:107177. https://doi.org/10.1016/j.chb.2021.107177

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Author contributions

The authors confirm their contribution to the paper as follows: study conception and design: RL, JY, HY; data collection: RL, JY, JC, LL; analysis and interpretation of results: RL, LY, JC; original draft preparation: RL, LY, JC, JY. All authors reviewed the results and approved the final version of the manuscript.

Competing interests

The authors declare no competing interests.

Ethical approval

The author sought and gained ethical approval from Research Ethics Committee of the Jing Hengyi School of Education at Hangzhou Normal University (No. 2022028) on June 20, 2022. All procedures in this study were in accordance with the institutional research and the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

Informed consent

Informed consent was obtained from all study participants prior to participation. Respondents' participation in this study was voluntary. Before the survey began, we stated the purpose of the study to the participants. A total of 11,784 sampled participants accepted to voluntarily participate in this study when they filled out the questionnaire after the researchers assured them of anonymity and that their responses were solely used for academic purposes.

Additional information

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