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Research article

A study of the impact of the new digital divide on the ICT competences of rural and urban secondary school teachers in China

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ABSTRACT

Teachers' competence in information and communication technology (ICT) applications can lead to a deeper integration of technology into the curriculum and improve the quality of education. However, its application and distribution issues could result in resource inequality and social injustice. Based on the ICT competency framework for teachers, the study investigates the variables influencing teachers' ICT competency. A prediction model of teachers' ICT competency is built using empirical data from secondary school teachers in Hebei Province, China, both in urban and rural settings. The study results show that a new digital divide does exist between urban and rural teachers and that differences in digital environment and digital literacy reflecting the new digital divide have different degrees of impact on teachers' ICT competence. Age and subject also affect teachers' ICT competence. In the new era, we can start with knowledge acquisition, knowledge deepening and knowledge creation to improve teachers' ICT competence.

1. Introduction

With the large-scale distribution and application of information technology (IT), the term "Digital Divide" has emerged, which is often used to express "the gap in access to information and communication technologies (ICT) by different individuals, households, businesses, or regions" [1,2]. Inevitably, ICT is reshaping education and being integrated into the curriculum [3], becoming a driving force for change and advancement of education and teaching methods [4]. Teachers need to improve their competencies based on the "education + IT" mindset [5] in order to creatively integrate IT with knowledge to facilitate effective learning [6] rather than mindlessly chasing innovations in form.

The term "digital divide" was first coined in 1999 by the United States National Telecommunications and Information Administration (NTIA) in Lagging Behind the Net: Defining the Digital Divide. Early research on the digital divide focuses on the differences in ICT ownership among different social groups [7], known as the "first digital divide" [8]. Susan P. Crawford [9] proposes the concept of "new digital divide", which initially refers to the differences in the use of digital devices by different students to support their learning tasks. Later, the definition is broadened to include the differences in digital skills used by IT subjects [10], along with its reflection of social and cultural capital [11], i.e., the "second digital divide" [12]. Additionally, it has been recommended that people should fully understand the impact of technology on their surroundings [13], as well as pay attention to the various impacts of using IT [14], i.e., the "third digital divide". In essence, these impacts are still generated by differences in people's digital skills, so this study collectively refers to the differences in people's skills and use of IT as the "new digital divide".

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Countries worldwide are aggressively getting ready to maximize the digital education environment, such as Finland [15] and the United States [16]. While there are specific policies in China focusing on bridging the "first digital divide" and advancing fairness in education through information technology [17], the focus on the "new digital divide" is just beginning. In addition, existing studies on the new digital divide have focused on the current status of the digital divide [18,19], development tendencies [20], and influencing variables [21–23]. There are more descriptions of phenomena and problems of the "new digital divide" [24], yet there is still a dearth of comprehensive studies on its causes, impacts, and remedies.

The different levels of categorization above indicate that the new digital divide is a more comprehensive and intricate concept, rather than standalone ICT access, and that the assessment of the new digital divide no longer centers on access to digital devices or the Internet but rather on the user's ability to apply ICT [25]. In education, teachers have the right to decide what, when and how to employ IT in teaching, so it is necessary to analyze teachers' ICT competence.

Teachers' ICT competence was first proposed at the 16th World Computer Congress (WCC) as the ability of teachers to identify, access, process, integrate, evaluate, analyze and synthesize digital resources using digital tools and accessories [26]. Research on teachers' ICT competence has mainly focused on conceptual interpretation [27–29], cultivation pathways [30], chronological development [31,32], enhancement strategies [33,34], and evaluation studies [35]. Most empirical research has focused on measuring and evaluating students' ICT competency [36,37], while those related to teachers' ICT competence are relatively rare. The findings indicate that teachers' practical use of ICT is not promising, with examples including teachers' inability to apply ICT in the classroom effectively [38], their lack of access to high-quality resources [39], their struggles to help students embrace technology for learning [40], etc.

The digital divide issue in developing countries is becoming a cutting-edge theme [41]. Research by Martin Hilber [42] also suggests that the access to and utilization of ICT facilities might mean challenges for developing countries for a long time. Furthermore, there has been a steady rise in research on the regional digital divide in recent years [43]. While in the field of education, researchers have focused more on the effects of the digital divide on adolescents [44], existing studies on teachers' ICT competencies have mainly focused on pre-service teachers [45,46] and university teachers [47], with a smaller number of studies on secondary school teachers.

Therefore, this study intends to explore the impact of the digital divide on the ICT competence of urban and rural secondary school teachers in China by analyzing the following four research questions.

Question 1. What is the general condition of ICT competence among secondary school teachers in Hebei Province?

	Knowledge Acquisition Skills	Knowledge deepening Competencies	Knowledge Creation Skills
Understand the Policy on the Use of IT in Education	Policy Understanding	Policy Application	Policy Innovation
Curriculum & Assessment	Basic Knowledge	Knowledge Application	Knowledge-based Social Skills
Teaching Methodology	ICT for Teaching & Learning	Complex Problem-solving	Self Management
Digital Technology Application	Application	Indoctrination	Transformation
Organization & Management	Standard Classroom	Collaborative Groups	Learning Organization
Teacher Professional Learning	Digital Literacy	Establishing a Professional Network	Innovative Teachers

Fig. 1. The ICT-CFT framework.

Question 2. What factors influence the ICT competence of urban and rural secondary school teachers?

Question 3. To what extent do the influencing factors affect the ICT competence of urban and rural secondary school teachers?

Question 4. What are the viable approaches to enhance urban and rural teachers' ICT competence and bridge the new digital divide (if it exists)?

1.1. Theoretical framework

1.1.1. ICT-CFT framework

Aiming to introduce the knowledge and skills related to the application of information technology in education, UNESCO released the ICT Competency Framework for Teachers (see Fig. 1) in November 2011 at its 36th General Conference. It also includes basic principles of the framework's preparation, levels of competence, expected goals, sample syllabuses, sample examination requirements, and so on. In 2016, UNESCO incorporated user feedback, benchmarked against the UN's 2030 Sustainable Development Goals, and, combined with the development of technologies, finally formulated the ICT Competency Framework for Teachers (3rd edition).

It reconstructs the ICT educational application competencies [48], 18 items in total, based on the three levels including KA (knowledge acquisition), KD(knowledge deepening), and KC(knowledge creation), as well as six practice dimensions—understanding policies on IT educational application, curriculum and assessment, pedagogical methods, application of digital skills, organization and management, and teachers' professional learning. It also illustrates that, in the practical teaching process, it is not enough for teachers to master ICT competencies and impart them to students, teachers should assist students in improving their problem-solving, teamwork, and capacity to learn by example to cultivate qualified citizens and outstanding talents for the upcoming digital society [49].

1.1.2. The TPACK framework

In the 21st century, the integration of information technology in education has become increasingly crucial. Instructors have to possess a solid basis in TPACK in order to facilitate effective integration [50]. According to Shulman [51], since teachers' pedagogical knowledge (PK) and content knowledge (CK) are not sufficient to meet students' learning needs, in practical teaching, teachers should use PK and CK as a basis for developing more effective teaching strategies to help students overcome complex subjects, this unique form of pedagogical knowledge is known as pedagogical content knowledge (PCK). Based on that, Koehler and Mishra [52] proposed

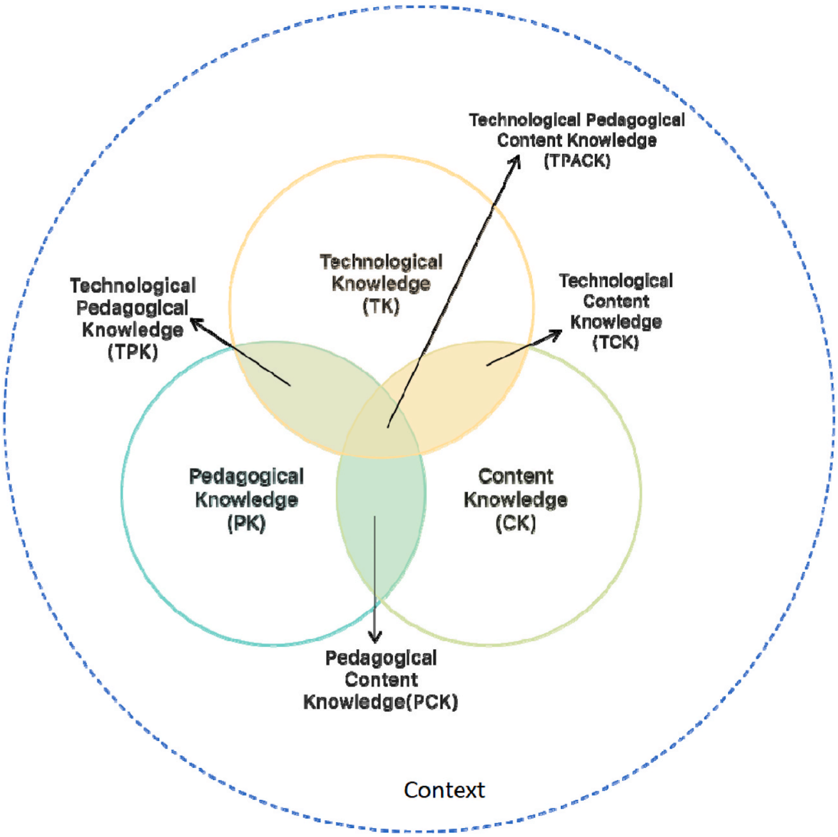

Fig. 2. TPACK model.

the TPACK framework (Technological Pedagogical Content Knowledge), which is depicted in Fig. 2 and takes into account technology, education and content knowledge in the educational setting and achieves a convergence of these three factors, which influences the use of ICT in education [53].

Established empirical studies have demonstrated that TPACK is inextricably linked to the development of teachers' ICT competencies [54], making it a crucial feature examined in this work. Within the framework of this investigation, TK denotes the capacity to utilize software such as the use of computers and multimedia in the teaching process, PK denotes the management of educational information resources as well as knowledge of lesson-planning expertise [55], and CK denotes specialized subject-matter knowledge.

2. Research design

2.1. Research subjects

On the one hand, Hebei Province is adjacent to Beijing, the capital of China thus it has more advanced educational infrastructure, but this is only true for schools in the city; rural regions farther away receive an unequal share of educational resources. On the other hand, secondary school teachers have fewer opportunities to participate in training and scholarly exchanges than university teachers who need further training and self-improvement. Therefore, this study focuses on secondary school teachers in Hebei Province and uses the whole cluster random sampling method [56] to select research participants from the target population to ensure that urban and rural teachers are included. These schools are divided into two groups (urban and rural) based on their geographical location. Subsequently, three schools are selected randomly from each group, bringing the number of participating schools to six. Two classes are randomly selected from each of the selected schools, 12 in total. Finally, all teachers in each selected class are included in the sample.

Research ethics are upheld at all stages of the study. Firstly, permission is sought and obtained from the college education office. Secondly, the purpose of the study is explained to the teachers before distributing the questionnaire, and they are free to decide whether to participate or not. Thirdly, the names of schools, classes or respondents are kept from any publications except for the city where the study is conducted. This study is determined to be exempt from approval by the Ethics Committee and followed the principles of the Declaration of Helsinki, all participants provided informed consent.

This study takes secondary school teachers in a certain area of Hebei Province as the research subject and adopts the form of online distribution powered by www.wjx.cn to carry out the questionnaire survey, a total of 629 questionnaires are collected. After eliminating the invalid questionnaire—such as those with answer time that is too short, or that omits important information—we obtain 622 valid questionnaires, with an effective collection rate of the questionnaire by 98.89 %, of which 318 come from urban areas, accounting for 51.1 % and 304 from rural areas, accounting for 48.9 %. Information of the subject is shown in Table 1.

2.2. Research Instruments

2.2.1. Digital divide measurement questionnaire

In this study, we draw upon the research of Li Jiaxin [57], which takes the distinctions between different social groups in terms of the digital environment (the first digital divide, comprising three dimensions: policy support, technical support, and hardware support) and digital literacy (the second digital divide, comprising three dimensions: information competence, online teaching ability, and tool use) as the specific indicators reflecting the digital divide.

2.2.2. ICT competence measurement questionnaire

The latest version of the ICT-CFT framework views teacher development as a lifelong learning process and, based on the actual

Table 1
Sample information (N = 622).

	Variable	Number of People	Percentage
School Location	Urban	318	51.1 %
	Rural	304	48.9 %
Gender	Male	160	25.7 %
	Female	462	74.3 %
Subjects Taught	Chinese	104	16.7 %
	Mathematics	102	16.4 %
	English	107	17.2 %
	Physics	79	12.7 %
	Chemistry	37	5.9 %
	Politics	43	6.9 %
	History	33	5.3 %
	Information Technology	29	4.7 %
	Geography	27	4.3 %
	P.E.	28	4.5 %
	Music	17	2.7 %
	Art	16	2.6 %

teaching practice of teachers, divides ICT competence into three levels (knowledge acquisition, knowledge deepening, and knowledge creation). It also breaks down ICT competence into six practice dimensions: organization and management, teaching methodology, application of digital skills, curriculum and assessment, and understanding the policy of IT education application. Additionally, the framework suggests that teachers should be trained to acquire subject-specific knowledge and pedagogical methods during the teacher training stage, which will facilitate their understanding of the relationship between ICT and teaching practice, or TPACK [48]. Consequently, the four aspects listed below will be employed in this article to gauge ICT competency:

① the level of each dimension of TPACK (The four dimensions of CK, TK, PCK, and TPACK are selected from the practical teaching and our research contexts), ② knowledge acquisition, ③ knowledge deepening and ④ knowledge creation.

2.2.3. Questionnaire reliability and validity test

Since the questionnaire uses the Likert five-point choice scoring system, SPSS24.0 is the foundation of our study. The test reveals that the Cronbach's α of each dimension is larger than 0.9 (see Table 2), indicating that the internal consistency of the questionnaire is better. Its overall reliability also achieves 0.992, a high degree of dependability. The KMO coefficient value of the questionnaire is 0.987 and the P value of Bartlett's test of sphericity is 0.000, while the factor loading coefficients values are all higher than 0.5, which further indicates that the questionnaire's validity is good (see Table 3).

3. Results

3.1. Descriptive statistical analysis of each dimension (RQ1)

According to Table 4, the mean value of the subjects' digital literacy and digital environment dimensions range from 3.6 to 3.9, which is at a medium level, indicating that the overall ICT competence of urban and rural teachers is low. The mean value of the digital literacy dimension is higher than that of the digital environment dimension, indicating that the digital environment is slightly insufficient in supporting the development of teachers' digital literacy. Whereas, in the teachers' TPACK framework, the TPACK value is the lowest ($M = 3.93$), the CK value is the highest ($M = 4.15$), and the teachers' CK ($M = 4.15$) and PCK ($M = 4.10$) are both higher than 4.0 and significantly higher than TK ($M = 3.94$) and TPACK ($M = 3.94$), indicating that teachers have a better grasp of the content knowledge but a lower level of competence in integrating technology into specific subject. Besides, the mean value of the three dimensions of knowledge acquisition, knowledge deepening and knowledge creation under the ICT-IFT framework shows a decreasing trend, indicating that there is still much room for teachers to deepen their competence in applying ICT to education.

The results of the independent sample *t*-test (see Table 5) show that urban teachers' scores on digital environment, digital literacy, TPACK, TK, PCK, knowledge acquisition, knowledge deepening, and knowledge creation are higher than those of rural teachers in each of the items, and the difference is significant ($sig = 0.000 < 0.05$), which suggests that the new digital divide does exist between urban and rural secondary teachers. Urban instructors have better access to digital environments than their rural counterparts, that is, greater levels of digital literacy and comparatively more substantial TPACK across the board.

3.2. Bivariate relationship between digital environment, digital literacy, TPACK and age (RQ2)

The purpose of the one-tailed test is to test whether the value of the overall parameter from which the sample takes is higher or lower than a particular value, while the two-tailed test tests whether there is any significant difference between the sample mean and the overall mean. According to the purpose of the study in this section, the values of the two-tailed test are taken in Table 6, and our specific analyses are as follows.

3.2.1. Correlation between age, CK, PCK and TPACK

Teachers' age is positively correlated with CK ($r = 0.143$, $p < 0.01$), PCK ($r = 0.153$, $p < 0.01$), and TPACK ($r = 0.088$, $p < 0.01$), while it is negatively correlated with TK ($r = 0.025$, $p < 0.01$), which indicates that the difference in the age of teachers leads to the different levels of teachers' TPACK competence, and that the older the teachers, the richer the CK, PCK, but weaker in technology application, and the disciplinary view of teaching leads to their inability to effectively use ICT to support the teaching process in the classroom and to make technology truly integrated into the curriculum.

Table 2
Measurement of questionnaire.

Questionnaire Dimension	Number of Questions	Cronbach Alpha
Digital Environment	8	0.948
Digital Literacy	15	0.973
TPACK	22	0.987
Knowledge Acquisition	6	0.965
Knowledge Deepening	6	0.976
Knowledge Creation	6	0.975
Total	63	0.992

Table 3
KMO and Bartlett's test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		0.987
Bartlett's Test of Sphericity	Approx. Chi-Square	59849.781
	df	1953
	Sig.	0.000

Table 4
Descriptive statistics.

Questionnaire Dimension	N	Mean	Standard Deviation
Digital Literacy	622	3.8874	0.81085
Digital Environment	622	3.6807	0.90049
CK	622	4.1559	0.79463
PCK	622	4.1031	0.79299
TK	622	3.9427	0.85530
TPACK	622	3.9399	0.86622
Knowledge Acquisition	622	3.8658	0.86070
Knowledge Deepening	622	3.6661	0.97655
Knowledge Creation	622	3.5166	1.09268
Number of Valid Cases	622		

Table 5
Results of independent sample t-tests for urban and rural teachers.

	urban and rural	N	Mean	Standard Deviation	Standard Error Mean
DE	urban	318	3.9461	0.85940	0.04819
	rural	304	3.4030	0.85899	0.04927
DL	urban	318	4.0983	0.78369	0.04395
	rural	304	3.6667	0.78064	0.04477
KA	urban	318	4.1169	0.79047	0.04433
	rural	304	3.6031	0.85391	0.04898
KI	urban	318	3.9696	0.86483	0.04850
	rural	304	3.3487	0.98706	0.05661
KC	urban	318	3.8899	0.90918	0.05098
	rural	304	3.1261	1.13266	0.06496
CK	urban	318	4.4465	0.63814	0.03579
	rural	304	4.8520	0.82871	0.04753
TK	urban	318	4.1771	0.78703	0.04413
	rural	304	3.6974	0.85627	0.04911
PCK	urban	318	4.3733	0.66035	0.03703
	rural	304	3.8205	0.82209	0.04715
TPACK	urban	318	4.2017	0.75070	0.04210
	rural	304	3.6661	0.89505	0.05133
ICT	urban	318	3.9921	0.81954	0.04596
	rural	304	3.3593	0.93680	0.05373

Table 6
Pearson relevance.

	DE	DL	CK	TK	PCK	TPACK	ICT
DE	1	0.801**	0.654**	0.700**	0.677**	0.728**	0.745**
DL	0.801**	1	0.789**	0.861**	0.803**	0.873**	0.811**
CK	0.654**	0.789**	1	0.840**	0.923**	0.933**	0.706**
TK	0.700**	0.861**	0.840**	1	0.842**	0.930**	0.815**
PCK	0.677**	0.803**	0.923**	0.842**	1	0.953**	0.739**
TPACK	0.728**	0.873**	0.933**	0.930**	0.953**	1	0.837**
ICT	0.745**	0.811**	0.706**	0.815**	0.739**	0.837**	1
AGE	0.108**	−0.030	0.143**	−0.025	0.153**	0.088*	0.055

**. At the 0.01 level (two-tailed), the correlation is significant.
*. At the 0.05 level (two-tailed), the correlation is significant.

3.2.2. Correlation between digital environment and TPACK

Digital environment is positively correlated with CK (r = 0.654, p < 0.01), TK (r = 0.700, p < 0.01), PCK (r = 0.677, p < 0.01), and TPACK (r = 0.728, p < 0.01), which indicates that the more convenient the digital environment, the more access teachers have to knowledge, and therefore, the higher teachers' CK, TK, PCK, and TPACK levels are higher.

3.2.3. Correlation between digital literacy, CK, PCK and TPACK

Digital literacy is positively correlated with CK (r = 0.789, p < 0.01), TK (r = 0.861, p < 0.01), PCK (r = 0.803, p < 0.01), and TPACK (r = 0.873, p < 0.01), which indicates that the higher the digital literacy of the teachers, the higher the tendency of the teachers to actively apply the technology in acquiring and transmitting knowledge, and therefore the teachers' CK, TK, PCK, and TPACK levels are higher.

3.2.4. Correlation between subject, CK, PCK and TPACK

Table 7 shows the values of the mean and standard deviation of the impact of subject variations on the TPACK and ICT competencies of urban and rural teachers. The degree of dispersion of the sample data is indicated by the standard deviation, which is the open square of the variance of the sample mean. For the nature of this study, the higher the standard deviation, the more noticeable the impact of the subject on the competencies of urban and rural secondary school teachers. The arithmetic mean of the absolute value of the departure of the variable values from the mean is known as the mean deviation, which is one of the values showing the degree of difference between the variable values. A more significant mean deviation indicates greater divergence of the sign values from the arithmetic mean and vice versa.

There are significant differences in the level of competence of the dimensions in the TPACK of teachers from different disciplines. In the effect of subject on CK (F = 12.107, p = 0.008 < 0.01), art teachers show the lowest level of content knowledge (M = 3.92), and the level of content knowledge in the disciplines of Music, Physical Education, and Fine Arts is relatively low as well, while the CK values of teachers in other subjects are generally high, with Information Technology teachers showing the highest CK value (M = 4.43). In the effect of subject on TK (F = 3.08, p = 0.000 < 0.001), IT teachers have the highest TK value (M = 4.30), followed by Geography teachers (M = 4.28), Physics teachers (M = 4.28), compared with Physical Education teachers (M = 3.70), with Fine Arts teachers (M = 3.70) displaying the lowest TK value in the subject impact on TK. In the effect of subject on PCK (F = 11.928, p = 0.003 < 0.01), the Information Technology teachers have the highest level of pedagogical knowledge (M = 4.37), followed by Physics teachers (M = 4.36), and Physical Education teachers show the lowest PCK values (M = 3.58). Subject-wise effects on TPACK (F = 2.903, p = 0.001 < 0.01) show that IT teachers have the highest TPACK values (M = 4.31), followed by Language (M = 3.92), Mathematics (M = 3.75), and Physical Education (M = 3.58) teachers. These results suggest that teachers of IT tend to focus more on the development of CK and less on TK.

Table 7
Effect of subjects on TPACK and ICT (mean and standard deviation).

Subject	Number	CK	TK	PCK	TPACK	ICT
Chinese	104	4.0505	3.8590	4.0728	3.9231	3.6250
		0.80832	0.91457	0.77303	0.91663	0.99422
Mathematics	102	4.0539	3.7810	3.9986	3.7537	3.4777
		0.75258	0.80496	0.77376	0.79456	0.84974
English	107	4.2664	3.9470	4.1442	3.9614	3.7108
		0.78853	0.83069	0.83241	0.86746	0.89202
Physics	79	4.3797	4.2827	4.3599	4.2421	4.1146
		0.77404	0.84410	0.73943	0.77324	0.86169
Chemistry	37	4.1081	3.8018	4.0541	3.8818	3.5180
		0.80696	0.86588	0.75017	0.81381	0.95654
Politics	43	4.0116	3.9302	3.9468	3.8517	3.5465
		0.87789	0.85930	0.85147	0.92512	1.03587
History	33	4.0076	3.7475	3.8831	3.7045	3.3788
		0.65991	0.79070	0.72268	0.80878	0.89499
Information Technology	29	4.4310	4.2989	4.3695	4.3103	4.0441
		0.77603	0.83735	0.82818	0.87540	0.87191
Geography	27	4.3704	4.2840	4.2698	4.2315	4.0329
		0.79473	0.78285	0.71465	0.78653	0.78420
P.E.	28	3.9821	3.7024	3.9796	3.5804	3.4544
		0.70029	0.74998	0.69738	0.98379	0.96214
Music	17	4.1324	4.0000	4.0420	4.0000	3.7418
		0.94007	0.88192	0.91997	0.85810	0.88670
Art	16	3.9219	3.7083	3.9286	3.8594	3.5139
		0.82522	0.76860	0.91992	0.81250	0.90187
Total	622	4.1559	3.9427	4.1031	3.9399	3.6828
		0.79463	0.85530	0.79299	0.86622	0.93343

3.3. Predictive model of teachers' ICT competence (RQ3)

3.3.1. Model estimation and parameter analysis

Digital environment, digital literacy, TPACK, age and other factors correlate relatively closely with teachers' ICT competency. In order to more accurately predict the level of teachers' ICT competence, we utilize multiple linear regression, whose mathematical model is Y = ε + β0 + β1x1 + β2x2 + … βpXp, in which each dimension, such as TPACK, age, and subject, serves as the explanatory variables X to indicate the changes in the explanatory variable Y (the level of teachers' ICT competence). The variable Y can be made up of two parts: first, the linear change part of Y caused by the changes of the five explanatory variables X, i.e., Y = β0 + β1X1 + β2X2 + … βpXp; second, the change part caused by other random factors, i.e., ε, β0 … βp, etc., and the βp part are all unknown parameters in the model, and ε is the random error.

The unstandardized regression coefficients, denoted by the letter "B" in the table, show how much each independent variable influences the dependent variable. Thus, additional examination of the empirical data in Table 8 yields each element's standardized regression coefficient β, from which the prediction model is obtained as follows.

Teachers' ICT Competence = −0.314 + 0.215*DE+0.135*DL+0.189*CK+0.222*TK+0.014*PCK+0.599*TPACK-0.004*AGE. where, TPACK as the largest predictor affects teachers' ICT competence, followed by the order of TK > DE > CK > DL > PCK to predict teachers' ICT competency.

3.3.2. Model statistical tests

Model statistical tests are used to explain the degree of influence of independent variables on teachers' ICT competence, including equation goodness-of-fit test, equation significance test, and equation coefficient significance test. The goodness-of-fit of equations is used to test the degree of explanation of independent variables such as self-efficacy and cognitive style on teachers' ICT competence level, which is expressed by the corrected unit decidable coefficient R2. According to Table 9, the R-value in the paper is 0.890, which indicates that all the independent variables can explain 89.0 % of the teachers' ICT competence. The test of significance of the equation is completed through the F-test, and the F-value in this paper is 335.901 ($p = 00.000 < 0.01$), which indicates that there is a significant overall linearity in the model of the regression equation. The coefficient significance test is completed by *t*-test, and the *t*-test corresponded to significant correlation coefficients with p-values <0.05, which shows that the influencing factors such as DE, DL, TK, CK, PCK, TPACK, and age have different degrees of influence on teachers' ICT competences.

Multiple linear regression confirms that factors like TPACK, age, and subject can predict teachers' ability to apply ICT. The outcome of Pearson's correlation coefficient test demonstrates that there is no significant multicollinearity between the components since the correlation coefficients between the anticipated independent variables are less than 0.5. The VIF value of this model varies between 1.200 and 6.287, and the tolerance range fluctuates from 0.121 to 0.833, which shows that the predictive model is reasonable.

3.4. Strategies for improving teachers' ICT competences (RQ4)

Teaching is not only an ICT application but a sophisticated educational endeavour. Therefore, the digital environment and digital literacy are only necessary but insufficient to guarantee teachers' ICT competence. Teachers play a crucial role in a technology-integrated classroom, and teachers' decision-making also affects all aspects of student learning. Teachers' ICT proficiency significantly boosts students' capacity for critical and creative thinking, problem-solving, communication, and collaboration by using ICT to enhance student learning efficiency and foster the development of students' digital skills. To this end, the following development strategies are proposed.

3.4.1. Promoting educational change and teacher development from a systemic perspective

In the process of innovating teaching methods, we should focus on the complementarity between the parts and the whole so that the six dimensions of practice (understanding the policy of IT application, curriculum and assessment, teaching methodology, application of digital skills, organization and management, and teachers' professional learning) can be targeted for change without losing sight of the other parts of the picture, which is in line with the idea of Capability Maturity Model for Information Construction in Schools, as put forward by Ma Ning [58].

Table 8
Multiple regression analysis for predicting teachers' ICT competencies.

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	−0.314	0.119		−2.637	0.009		
	AGE	−0.004	0.002	0.041	2.022	0.004	0.833	1.200
	DE	0.215	0.033	0.207	6.569	0.000	0.338	2.957
	DL	0.135	0.053	0.117	2.537	0.001	0.158	6.324
	CK	0.189	0.059	−0.161	−3.187	0.002	0.132	7.555
	TK	0.222	0.053	0.204	4.215	0.000	0.145	6.918
	PCK	0.014	0.062	0.012	0.220	0.006	0.121	8.287
	TPACK	0.599	0.048	0.556	12.571	0.000	0.172	5.801

a. Dependent variable：ICT.

Table 9
Covariance diagnosis.

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change statistics					Durbin Watson
					R Squared change	F Amount of variation	Degree of freedom 1	Degree of freedom 2	Significance F Amount of change	
1	0.890[a]	0.793	0.791	0.42716	0.793	335.901	7	614	0.000	1.670

a. Predictors: (constants), TPACK, AGE, DE, CK, DL, TK, PCK.
b. Dependent variable：ICT.

3.4.2. Personalized teacher training to cater for different teachers

The three hierarchical structures proposed by ICT-CFT echo other scholars' description of the different developmental stages of teachers' application of ICT to teaching from an ecological perspective (learning and imitation, confusion and wandering, professional evolution and integration, and innovation and development) [49], which are also the three typical stages of teacher development. In order to optimize the potential of teachers, we should tailor teacher preparation programs to individual instructors based on their unique personal traits in addition to the general direction of teacher education.

3.4.3. Enhancing teachers' reading of information technology policies in education

IT policies exist and differ globally, nationally, and locally. In recent years, China has made significant investments in teacher development, introducing several development plans that incorporate the benefits of ICT for preserving national stability, developing science and technology, and promoting educational justice [59]. Teachers' study, comprehension and application of relevant policies are of great significance to the deep integration of IT and teaching practice, which is an essential step in the innovation of integrated information technology education.

3.4.4. Digital teachers should ultimately become innovators of technological knowledge

According to the ICT-CFT framework, educators should transition from just using technology to becoming proficient users and, eventually, creative designers and users of technology. Additionally, the focus shifts from instructors' broad usage of specific technologies to an awareness of the intricate relationships between TK, CK, and PK and the development of adaptable pedagogical decision-making abilities to enhance student learning. On the one hand, teachers should not be limited to the use of certain specific technologies but should also pay attention to the extension of the use of technology. For instance, digital stories are an essential addition to PowerPoint presentations and can encourage teachers to consider technology use from a different angle. On the other hand, in the face of the frequent updating of IT, teachers need to be aware of its benefits and drawbacks. They must also understand how to choose and create various IT applications based on the needs of their students. Ultimately, incorporating technology into the classroom is a complex topic that requires case-by-case analysis.

3.4.5. Strengthening the construction of IT infrastructure and the cultivation of teachers' ICT competency

The existence of the digital divide is inevitable and cannot be ignored. If the digital environment and digital literacy necessary to carry out online teaching are in a state of scarcity for rural teachers, then it may have a more significant marginal effect relative to urban teachers; that is, when the digital environment and literacy of rural teachers are improved, the benefits will be more significant than urban teachers [57]. Thus, we should improve teacher ICT competency training to ensure that the digital environment and digital literacy work hand in hand to create new digital campuses, train a new generation of digital teachers, and energize the cause of nurturing innovative digital talent. This will help to close the growing digital divide between urban and rural teachers while also popularizing infrastructure construction to ensure educational equity.

4. Discussion

The digital divide has been a significant impediment to educational equity. Previous research has shown that education [60], income [61], gender [62], age [63]and infrastructure [64] are important factors influencing the digital divide, and there is also evidence that geography plays a vital role in the digital divide [65]. With an emphasis on education, our goals are to build multiple regression models to help future researchers predict teachers' ICT competence and validate previous research by investigating the factors affecting the ICT competence of secondary school teachers in China's rural and urban areas. In two locations in China, we gathered and examined data from 622 secondary school instructors in thirteen courses.

The first research objective of this study is to explore the situation of ICT competence among urban and rural secondary school teachers and whether a new digital divide exists between them. Analysis of the descriptive statistics reveals that there is indeed a digital divide between urban and rural secondary school teachers and that urban and rural secondary school teachers have poor ICT competence in general. However, it is worth noting that rural teachers seem to possess more solid CK than urban teachers, and the reasons for this interesting phenomenon deserve further subsequent research. Moreover, despite the unprecedented widespread popularity of IT, teachers still need to integrate IT effectively into practical teaching and learning—the reasons for this discrepancy between IT and teachers' ICT competency merit further research. The first step is identifying the variables influencing teachers' ICT competency in the information age.

The second research objective of this study is to figure out what affects teachers' ICT proficiency in secondary schools in both urban and rural areas, as well as how these characteristics relate to one another. According to the data, there appears to be a link between ICT competency and age, subject, TK, TPACK, PCK, and CK in digital education. Older teachers have lower levels of TK and TPACK; they have limited theoretical knowledge of ICT, and it is difficult for them to integrate technology with the curriculum in practical teaching effectively. Differences in subjects also lead to differences in the levels of ICT competence, and IT Teachers, physics teachers, geography teachers, etc., have more potent ICT competencies, indicating that the high technological demand in actual teaching will also promote the improvement of teachers' ICT competencies. It is worth noting that the study's impacting elements seem not specific to China. For example, Rezende [66] indicates that teachers' ICT competence in Brazil is affected by ICT access during the epidemic, and Ananto [41] discovers that the level of teachers' activeness in the use of digital tools in Indonesia is correlated with age.

The third research objective of this study is to construct a multiple linear regression model to predict the ICT competence of urban and rural secondary school teachers. The final mathematical model obtained in this study is

$$\text{Teachers' ICT Competence} = -0.314 + 0.215*DE + 0.135*DL + 0.189*CK + 0.222*TK + 0.014*PCK + 0.599*TPACK - 0.004*AGE.$$

TPACK, as the most influential factor predicting teachers' ICT competence, complements the established research showing that teachers with strong ICT competence can contribute to the development of TPACK of other teachers [67], although this is different from the conclusion of M.-L. Schmitz [68], based on structural equation models, that transformational leadership practice is a predictor of ICT competence among Swiss high school teachers, which may attribute to the differences in research dimensions related to the study context.

The fourth research objective of this study is to propose enhancement strategies in response to the new digital divide that exists between urban and rural teachers. In the previous section we have made five recommendations in terms of policy deliberation, technological innovations, infrastructure construction, pedagogical approaches and teacher literacy enhancement. In terms of strategy implementation, it needs to be paired with local teaching and learning practices, based on specific schools, and with specific curriculum content, in order to lay the foundation for successful integration of teaching and technology.

5. Conclusion

5.1. *Implications*

The theoretical implications of this study are as follows. First, the results validate the relationships between ICT competence and digital literacy, the digital environment, TPACK dimensions, and the subject and age of secondary school teachers in urban and rural areas. Additionally, multiple linear regression models are built to help predict ICT competence to a certain degree. Furthermore, the results of this study might improve comprehension of the functions of every component examined and establish the groundwork for the subsequent creation of more sophisticated evaluation frameworks.

The practical implications of this study are as follows. Firstly, by assessing the current status of the ICT competence of urban and rural secondary school teachers, this study attempts to provide educators and policymakers with valuable reference practices in assessing the ICT competence of urban and rural secondary school teachers. Secondly, this study is expected to raise the awareness of urban and rural secondary school teachers regarding enhancing their ICT competence to meet the demands of digitally driven educational environments. Urban and rural secondary school teachers can be better prepared for successful digital practices by identifying their weaknesses in incorporating ICT into their teaching practices. Thirdly, the long-term goal of this study is to contribute to the overall improvement of the digital pedagogical competence of urban and rural secondary school teachers. Well-trained urban and rural secondary school teachers with a solid foundation in digital competence will play a vital role in contributing to the effectiveness and innovation of digital pedagogical practices within the education system.

5.2. *Limitations and future study*

This study investigated the ICT competence of urban and rural secondary school teachers, but the study still has some limitations. Firstly, this study only presented a hypothetical model and did not compare it with other possible models. Although the indices were statistically acceptable and demonstrated the validity and reasonableness of the current model, the research design might have been more comprehensive if compared with alternative models. Secondly, instructors at secondary schools in rural and urban areas may see changes in their ICT competency over time. Therefore, the span of this study may be increased in the future to conduct further research and determine the validity of the current findings. Finally, the current analyses are primary because of the vast sample size and diverse range of participants in this study; more comprehensive analyses might be carried out in the future to produce more intriguing results.

5.3. *Concluding remarks*

In the context of global digital education, technology will have a revolutionary impact on education, and the ultimate point of impact is still on teachers. Therefore, the cultivation and development of teachers' ICT competence in the information age have become the focus of attention of all countries. In order to give teachers the technical support they need, treat them as innovators, designers, and users of information technology in the classroom, and give them more options for creating instructional strategies that will best support the literacy development of teachers with varying ICT proficiency levels, we should be aware of the variations in ICT competencies among teachers of different disciplines to improve the limitations of ICT in the process of educational and pedagogical applications. To better contribute to global economic and social development, we must raise the standard of teacher training and produce a new generation of digital educators who are bold enough to take on societal challenges, adjust to the IT environment, and endorse reforms in the classroom.

Data availability statement

The data associated with my study has not been deposited into a publicly available repository due to privacy or ethical restrictions. The data that support the results presented in this paper are available from the corresponding author, upon reasonable request.

Ethics approval and consent to participate

Waiver of Ethics approval was obtained from the Institutional Ethics Committee of Jilin University. Informed consent was received from all participants. Participation in the survey was voluntary as participants could decline to participate at any time during the study.

CRediT authorship contribution statement

Wei Zhao: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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