

Research Article

# The Influence of Digital Literacy Challenges on the Enhancement of Teaching Abilities Among Rural Educators: Evidence from Western Guangdong, China

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## Abstract

Rural teachers play a pivotal role in the digital transformation of rural education, acting as both advocates and implementers. They also bear the significant responsibility and mission of fostering the development of digital villages. However, while the digitization of education presents valuable opportunities for rural teachers, their limited digital literacy hinders their capacity to engage effectively in the transformation process. This study aims to examine the current state of digital literacy among rural primary and secondary school teachers and investigate the underlying factors contributing to the challenges that impede the enhancement and growth of their digital competencies. The study examined and analyzed the digital literacy of 1,220 rural teachers in western Guangdong, China. The findings revealed significant regional disparities across five dimensions: professional development, digital awareness, digital application, knowledge and skills related to digital technology, and digital social responsibility among teachers. Notably, the degree of these differences increased with the remoteness of the region. Furthermore, the impact of digital literacy on teacher roles was found to be particularly significant for ordinary teachers as well as for principals and administrators. In addition, there are notable disparities in professional development among teachers at various educational stages. The study identified that the primary challenge hindering the enhancement of digital literacy among rural teachers in China is the difficulty in transforming digital awareness and skills. Furthermore, there exists a significant hierarchical differentiation in the digital literacy levels of these educators. The issue of unbalanced professional development is particularly pronounced across different educational stages. The findings not only offer new empirical evidence for advancing the digital literacy framework for rural teachers in China but also serve as an important reference for research aimed at improving the digital literacy of rural educators in other regions.

## Keywords

Rural Teachers, Primary and Secondary School Teachers, Digital Literacy, Professional Development, Digital Awareness

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## 1. Introduction

With the rapid advancement of information technology, the integration of digital technologies within the educational sector has emerged as a significant trend in global educational reform. In November 2021, the Central Cyberspace Affairs Commission issued the "Action Outline for Improving Digital Literacy and Skills Among All Citizens," which emphasized that digital literacy and skills constitute fundamental qualities and competencies essential for adapting to a digital society [1]. It encompasses a comprehensive array of capabilities, including obtaining, creating, applying, evaluating, interacting with, sharing, innovating upon, ensuring security in, and adhering to ethical norms regarding digital content. As professionals in the field of education, primary and secondary school teachers need to continually enhance their digital literacy to meet the rapidly evolving demands of contemporary society and to effectively engage with the burgeoning wave of digital education [2].

However, digital literacy encompasses not only the mastery of fundamental computer operation skills but, more importantly, the ability to adeptly employ digital technology to enhance teaching and learning activities. Given that primary and secondary school teachers are the principal agents of education, their level of digital literacy is directly linked to the enhancement of educational quality and the development of students' innovative capabilities. In April 2025, the Ministry of Education, along with nine other departments, issued a set of opinions aimed at accelerating the digitization of education. The document proposed several initiatives, including the continuous enhancement of the public service functions of the national platform, promoting its in-depth application across all regions, and facilitating the integration and effective governance of educational data, with the aim of accelerating the digitization of education and assisting in the modernization of education [3]. Guangdong Province, recognized as one of the most dynamic and innovative regions in China, imposes even higher standards for the digital literacy of primary and secondary school teachers compared to other areas. With government initiatives promoting the integration of technology in education, a substantial array of digital educational resources and platforms has been made available for use in primary and secondary schools throughout Guangdong Province which also puts higher demands on teachers' digital literacy. Only by achieving a higher level of digital proficiency can educators effectively leverage these resources and platforms for instructional design, curriculum development, and personalized teaching [4].

In reality, researchers have identified specific gaps and challenges in the digital literacy levels of primary and secondary school teachers in Guangdong Province. On one hand, some educators continue to experience difficulties and exhibit resistance towards the application of digital technology, coupled with a lack of relevant knowledge and skills. On the other hand, technological advancements are occurring at an accel-

erated pace, necessitating that teachers engage in continuous learning and adapt to new technological tools and resources. Consequently, advancing the digital development of rural education in Guangdong Province, China, is fundamentally contingent upon enhancing the digital literacy of rural teachers [5]. A comprehensive understanding of the current status of digital literacy among rural primary and secondary school teachers in Guangdong Province will enable educational policymakers and administrators to assess the readiness, skill levels, and challenges encountered by these educators within the realm of digital education. This insight will facilitate targeted training initiatives and support for rural primary and secondary school teachers across various counties in Guangdong Province.

## 2. Literature Review

### 2.1. Digital Literacy

With the widespread adoption of digital work and learning environments, digitalization and informatization have increasingly become central to human life and practice. In this context, digital literacy emerges not only as a crucial factor in facilitating the digital transformation of education but also as an essential quality for future educators [6]. It reflects teachers' ongoing self-improvement efforts to adapt to the trends of educational digitalization, with its level directly influencing the effectiveness of educational digital transformation. In 2017, Redecker proposed the Digital Competencies for Educators (DigCompEdu) framework defining profession-specific digital competencies to be mastered by European educators across five competency areas of information, communication, content creation, security, and problem solving, with the aim of capturing the potential offered by digital technologies to enhance and reform education in European member states. With the inclusion of new technologies and the use of different terminology, the framework has been updated to DigComp 2.1, which defines eight proficiency levels for 21 competency indicators and serves as a comprehensive framework for teachers' digital competencies [7]. In November 2022, China's Ministry of Education released the Digital Literacy for Teachers standard, which specifies the digital technology application skills, including the ability to access, process, use, manage, and evaluate digital information and resources, as well as the ability to identify, analyze, and solve problems in teaching practice, and defined digital awareness, digital technology knowledge and skills, digital application, digital social responsibility, and professional development as the first-level dimensions for evaluating teachers' digital literacy [8]. Teachers need to continuously improve their digital skills, integrate digital technologies into their teaching, and hold the awareness and responsibility to innovate and change in order to improve the effectiveness and

quality of their teaching.

## 2.2. Digital Literacy of Educators in the Context of Urban-rural Disparities

In the context of the urban-rural dichotomy, the impact of geographical factors on teachers' digital literacy is particularly pronounced. In China, basic education in rural areas has historically lagged behind that in urban regions, and the uneven distribution of hardware resources has further exacerbated the "development gap" between urban and rural education [9]. The evident disparity in digital literacy between urban and rural educators perpetuates the "digital divide," presenting a significant challenge to educational equity. It is widely acknowledged that inequalities in digital infrastructure contribute to the difficulties faced by rural teachers and students in accessing digital devices and internet connectivity, thereby increasing obstacles to enhancing teachers' digital literacy. Some experts confirmed that rural schools are currently unable to meet the demands of digital teaching and learning, particularly in terms of hardware provisioning [10-13]. The primary concerns for rural teachers include Internet connectivity, teaching equipment, and essential digital skills-these represent fundamental challenges in implementing effective digital education. The inherent disparities between urban and rural areas hinder the ability of rural schools to keep pace with technological advancements; equipment failures often go unrepaired for extended periods, resulting in teachers being unable to utilize these devices effectively. Consequently, improvements in digital literacy through practical application remain elusive, as educators can only engage with theoretical aspects of technology [14]. Thus, the gap in urban-rural development coupled with the uneven distribution of educational resources exacerbates the need for enhanced digital teaching skills among rural educators. This deficiency in equipment further restricts teachers' hands-on experience with educational technologies and impedes their overall digital literacy development.

## 2.3. Weak Digital Awareness Among Rural Teachers

Rural teachers, as pivotal agents in the advancement of digital education within villages, possess attitudes towards professional development that are particularly influenced by their subjective perceptions of its advantages and disadvantages. These perceptions directly impact their motivation to engage in professional development activities. Soekamto et al. demonstrated that rural teachers in Indonesia and the Middle East exhibit a lack of digital awareness regarding the utilization of digital tools for teaching and learning [15]. The phenomenon is similarly prevalent among rural educators in China. Chinese scholars have identified multiple factors contributing to the low willingness of rural teachers to enhance their digital literacy. Cui and Xu argue that these educators

have long existed in a "fringe zone" concerning digitalization, characterized by insufficient information, incomplete knowledge and skills related to information technology, as well as a lack of practical experience-resulting in an absence of identification with digital teaching tools [16]. Wu and Wang concluded that the irrational age structure among rural teachers in China has adversely affected the overall development of their digital literacy [4]. The demographic composition within Chinese rural schools is marked by a limited proportion of young educators alongside older teachers; this situation leads to diminished team dynamics and reluctance toward enhancing digital literacy [17]. Furthermore, Zhang et al. found that rural teachers face burdensome teaching responsibilities coupled with low salaries and limited opportunities for career advancement-factors which contribute significantly to their disinclination to improve their digital competencies [18]. In terms of engaging with digital education initiatives, it appears that rural teachers possess only basic operational skills related to using digital devices without having transitioned from these foundational skills towards achieving comprehensive digital literacy.

In addition, rural school administrators and teachers lack a deep understanding of education digitization, seeing it as a simple application of digital technology in educational scenarios, lacking the concept of applying digital technology to innovate teaching and learning activities, and using digital technology only as a short-term emergency tool or measure. Qu and Gao acknowledged that some rural principals and administrators have a certain degree of digital literacy, but lack a certain degree of digital top-level design and digital governance [19]. The result suggests that although rural principals and administrators have some understanding of digital technology, they fail to deeply understand the connotation and value of digital transformation in education and lack the awareness of it as a tool for systemic change. Huang and Zhang further verified that some rural principals in China did not pay enough attention to the digital transformation of education and neglected the formulation of the school's digital development vision and goals, which seriously affected the generation and development of rural teachers' digital literacy [20]. This finding suggests that rural principals and administrators lack firm will and clear direction in promoting digital transformation in rural schools, and fail to promote digital transformation as a core strategy for school development. It shows that rural principals and administrators lack initiative and long-term planning in the application of digital technology in their practical work, and are more reactive than proactive in exploring and applying digital technology to improve the quality of education and teaching. Although rural principals and administrators possess a certain degree of digital awareness, there is still an obvious lack of digital will and willingness, which adversely affects the digital transformation of education in their schools.

### 3. Materials and Methods

#### 3.1. Instrument

To verify the differences in digital literacy among primary and secondary school teachers in rural areas of the Guangdong Province's western region, this study designed and implemented a structured questionnaire survey. The construction of the questionnaire was based on the digital literacy framework published by the Ministry of Education of China, while also taking into account local realities. Targeted adjustments were made to measurement items and dimensions to ensure alignment with the actual conditions and cultural background of local teachers, thereby enhancing both regional adaptability of data and reliability of research findings. These optimization measures were completed based on preliminary surveys and

expert recommendations, ensuring that the concepts and language used in the questionnaire would be familiar to respondents and easy for them to understand.

In terms of questionnaire design, a five-point Likert scale was employed due to its simplicity and efficiency, which has led to its widespread adoption in social science research. The scale includes five options ranging from (1) "Strongly Disagree" to (5) "Strongly Agree," aimed at measuring teachers' levels of agreement with various statements. The approach allows for precise capture of differences in rural primary and secondary school teachers' perceptions regarding their own digital literacy. The five dimensions summarizing digital literacy—digital awareness, digital knowledge and skills, digital application, social responsibility related to digitization, and professional development—are detailed as shown in the Table 1 below.

*Table 1. Explanation of Dimensions of Digital Literacy (MOE, 2023).*

Dimensions	Description
Digital Awareness	Digital Awareness encompasses the conscious reflection of objectively existing digital-related activities within educators' minds, including digital cognition, digital willingness, and digital will.
Digital Applications	Digital Applications encompass the digital technology knowledge that educators should be well-versed in, as well as the digital skills they must acquire to effectively engage in their daily teaching and educational activities, including digital technology knowledge and digital technology skills.
Digital Technology Knowledge and Skills	Digital Technology Knowledge and Skills refer to the ability of teachers to apply digital technology resources in educational and teaching activities, including digital teaching design, digital teaching implementation, digital academic assessment, and digital collaborative education.
Digital Social Responsibility	Digital Social Responsibility refers to the ethical cultivation and behavioral norms that educators are expected to uphold in digital activities. It encompasses adherence to legal and moral standards, as well as the protection of digital security.
Professional Development	Professional Development refers to the ability of teachers to promote their own and the community's professional development by utilizing digital technology resources, including digital learning and training, as well as digital teaching research and innovation.

#### 3.2. Data Collection

The study conducts an in-depth investigation using primary and secondary school teachers from rural areas of Guangdong Province, China, as the sample population. To ensure the representativeness and reliability of the sample, a stratified sampling method was employed for the survey. Initially, the researchers divided the survey area into three levels: county towns, towns, and villages. Random selections of primary and secondary school teachers were made from each level to form the sample. It stratified sampling approach effectively reflects differences among various geographical and administrative units to a certain extent. A total of 1,220 primary and secondary school teachers participated in the survey following the sampling process.

### 4. Results

#### 4.1. Reliability and Validity Analysis

Reliability refers to the stability and consistency of results obtained from a test or measurement instrument. A higher reliability coefficient indicates a smaller error in the measurement outcomes. In social science research, scales typically encompass multiple dimensions; therefore, it is essential not only to provide an overall reliability coefficient but also to present the reliability coefficients for each dimension as a reference. Ideally, these coefficients should exceed 0.80, with values above 0.90 being preferable. In this study, the reliability of the digital literacy questionnaire was analyzed and

the results are shown in Table 2. The data in Table 2 shows that the reliability coefficient of the final questionnaire is

0.976, which is greater than 0.9, which indicates that the reliability quality of the research data is high.

**Table 2.** Reliability Analysis of the Digital Literacy Questionnaire.

Dimension	The number of items	Cronbach $\alpha$ Coefficient	Total Cronbach $\alpha$ Coefficient
Professional Development	5	0.931	
Digital Awareness	3	0.928	
Digital Applications	3	0.915	0.976
Digital Technology Knowledge and Skills	4	0.937	
Digital Social Responsibility	3	0.909	

The validity study is a methodological approach employed to assess the reasonableness and meaningfulness of research items. As illustrated in Table 3, validity analysis incorporates several indicators to evaluate the level of data validity. The KMO (Kaiser-Meyer-Olkin) value serves as an indicator for determining the appropriateness of information extraction. In this survey, the KMO value is 0.972, which exceeds the threshold of 0.6, thereby indicating that effective information extraction from the data is feasible. It suggests that the selected method is appropriate for information extraction purposes. Secondly, commonality functions as an indicator used to eliminate unreasonable research items. As presented in Table 3, all research items exhibit commonality values exceeding 0.4, signifying that their respective information can

be effectively extracted. Thirdly, the variance explained value indicates the extent of information extraction achieved by each factor under consideration. The explained variance rates for the five factors discussed are as follows: 24.886%, 18.451%, 16.661%, 15.378%, and 10.949%. Cumulatively, these factors yield a total explained variance of 86.326%, surpassing the critical threshold of 50%. This finding confirms that the selected factors are indeed effective in extracting substantial amounts of information from the research items. In summary, through a combined analysis of these indicators, we can ascertain the validity level of our data effectively; thus demonstrating that not only can it be extracted efficiently but also affirming its reliability and validity within this research context.

**Table 3.** Digital Literacy Validity Analysis Results.

Items	Factor Loading Coefficient					Commonality (common factor variance)
	Digital Technology Knowledge and Skills	Digital Awareness	Digital Social Responsibility	Professional Development	Digital Applications	
PD1				0.813		0.915
PD2				0.750		0.881
PD3				0.491		0.834
PD4				0.639		0.876
PD5				0.637		0.861
DA1		0.669				0.844
DA2		0.692				0.883
DA3		0.661				0.849
DApp1					0.637	0.778
DApp2					0.548	0.879
DApp3					0.707	0.889

Items	Factor Loading Coefficient					Commonality (common factor variance)
	Digital Technology Knowledge and Skills	Digital Awareness	Digital Social Responsibility	Professional Development	Digital Appli- cations	
DTKS1	0.759					0.869
DTKS2	0.720					0.873
DTKS3	0.671					0.858
DSR1			0.634			0.834
DSR2			0.792			0.880
DSR3			0.718			0.871
Eigen (Initial)	12.276	1.019	0.516	0.441	0.423	-
% of Variance (Initial)	72.213%	5.992%	3.036%	2.595%	2.490%	-
Cum.% of Variance (Initial)	72.213%	78.205%	81.241%	83.836%	86.326%	-
Eigen (Rotated)	4.231	3.137	2.832	2.614	1.861	-
% of Variance (Rotated)	24.886%	18.451%	16.661%	15.378%	10.949%	-
Cum.% of Variance (Rotated)	24.886%	43.337%	59.998%	75.377%	86.326%	-
KMO value	0.972					-
Bartlett's Test of Sphericity	24251.922					-
df	136					-
P value	0.000					-

## 4.2. An Analysis of Variations in Digital Literacy Across Teachers' Work Areas

By analyzing the digital literacy competencies of primary and secondary school teachers across various regions, we can gain insights into the disparities in professional development, digital awareness, digital application skills, knowledge of digital technologies, and social responsibility related to digital engagement. The analysis aids in identifying challenges and bottlenecks in the preparedness of primary and secondary school teachers regarding their digital literacy within the context of a digitally-driven educational environment. Furthermore, early detection and resolution of issues pertaining to the digital divide can mitigate disparities between different

regions and foster educational equity. Ultimately, the endeavor contributes to enhancing the overall digital literacy of primary and secondary school educators.

The analysis of variance was employed to examine the differences across five dimensions of professional development: digital awareness, digital application, knowledge and skills in digital technology, and digital social responsibility within the educational context. As illustrated in Table 4, samples from various regions demonstrate statistically significant differences regarding professional development, digital awareness, digital application, knowledge and skills in digital technology, and digital social responsibility ( $p < 0.05$ ). It indicates that primary and secondary school teachers across different regions exhibit notable variations in these five aspects of digital literacy.

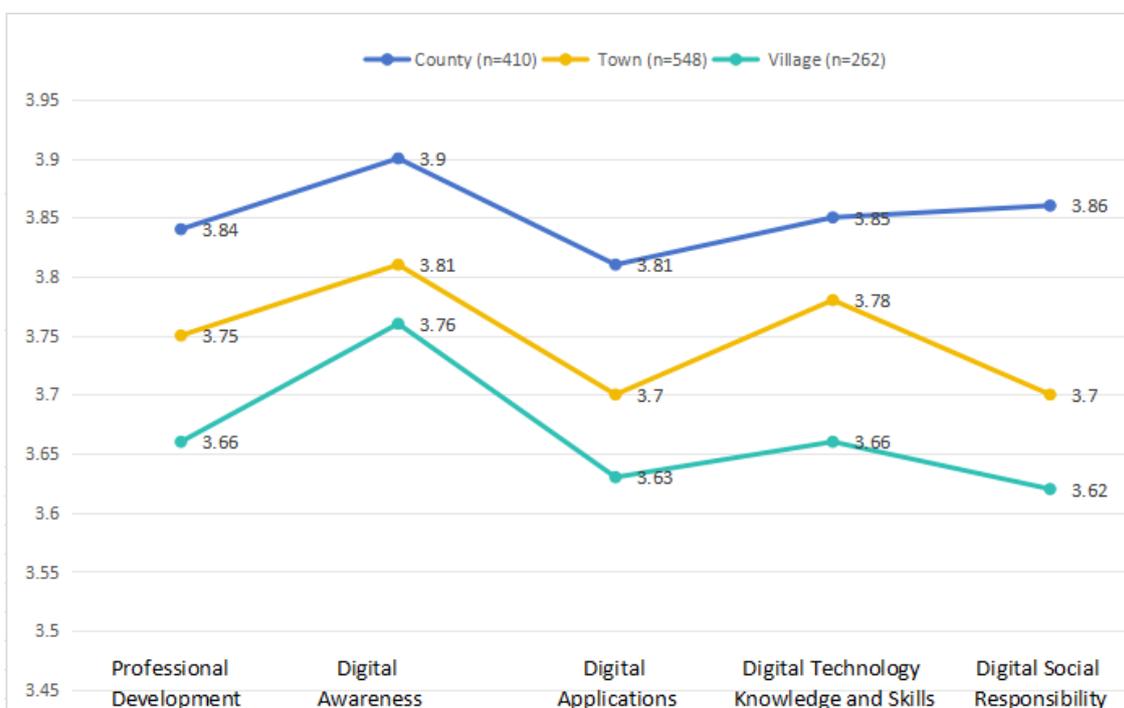
**Table 4.** Analysis of Variance Results for Teachers' Digital Literacy Competencies in Work Areas.

	Teachers' Work Areas (Mean ± standard deviation)			F	p
	County (n=410)	Town (n=548)	Village (n=262)		
Professional Development	3.84±0.70	3.75±0.68	3.66±0.71	5.643	0.004**
Digital Awareness	3.90±0.70	3.81±0.66	3.76±0.68	3.669	0.026*
Digital Applications	3.81±0.73	3.70±0.74	3.63±0.71	5.491	0.004**
Digital Technology Knowledge and Skills	3.85±0.75	3.78±0.67	3.66±0.73	5.970	0.003**
Digital Social Responsibility	3.86±0.73	3.70±0.74	3.62±0.69	9.574	0.000**

\*  $p < 0.05$  \*\*  $p < 0.01$

As illustrated in Figure 1, there is a negative correlation between the remoteness of a region and the mean scores of teachers' professional development, digital awareness, digital application, digital technology knowledge and skills, and digital social responsibility within the context of digital literacy. In other words, as the geographical distance increases, teachers' performance across these five dimensions of digital literacy tends to decline. Guillán-Gómez et al. argued that insufficient educational resources constitute a significant barrier to enhancing teachers' digital literacy in remote areas [21].

Moreover, among the five components of digital literacy assessed, it is noteworthy that while the mean score for digital awareness is relatively high, that for digital application ranks as the lowest. The finding indicates that although rural primary and secondary school teachers possess an understanding of the significance of digitization, their capacity to effectively implement digital technologies in actual teaching practices remains limited. While these educators recognize the importance of embracing digitization, the recognition has not been adequately translated into practical application skills or professional growth.



**Figure 1.** ANOVA Results of Digital Literacy Competencies in Teachers' Work Area.

### 4.3. An Analysis of the Disparities in Digital Literacy Among Rural Teachers' Positions

According to the data presented in Table 5, there are significant differences among the positions of rural primary and secondary school teachers regarding professional development, digital awareness, digital application, knowledge and skills related to digital technology, as well as digital social responsibility. Furthermore, these aspects-professional development, digital awareness, digital application, knowledge and skills pertaining to digital technology, and digital social responsibility-exhibit a statistically significant level of 0.01 ( $F > 5.914$ ;  $p = 0.000$ ). It indicates that the levels of development or performance across different teacher positions in

these five areas are markedly distinct; such differences are not merely due to random fluctuations but rather reflect statistically significant variations.

Analyzing the overall average scores reveals that principals have the highest average score, followed by subject leaders/grade leaders. Middle-level cadres rank next in terms of average score while ordinary teachers exhibit the lowest scores. The hierarchy suggests that within these five dimensions of digital literacy, principals demonstrate superior performance compared to subject leaders/grade leaders; subject leaders/grade leaders outperform middle-level cadres; and middle-level cadres exceed ordinary teachers in their respective performances.

**Table 5.** The Disparities in Digital Literacy Among Rural Teachers' Positions.

	Rural Teachers' Positions (Mean $\pm$ standard deviation)				F	p
	Ordinary Teachers (n=898)	Subject Leaders/Grade Leaders (n=127)	Middle-Level School Administrator (n=165)	Principals (n=30)		
Professional Development	3.71 $\pm$ 0.68	3.91 $\pm$ 0.63	3.86 $\pm$ 0.80	4.03 $\pm$ 0.67	6.345	0.000**
Digital Awareness	3.79 $\pm$ 0.66	3.97 $\pm$ 0.63	3.88 $\pm$ 0.79	4.17 $\pm$ 0.53	5.914	0.001**
Digital Applications	3.67 $\pm$ 0.71	3.89 $\pm$ 0.74	3.81 $\pm$ 0.85	4.13 $\pm$ 0.57	7.635	0.000**
Digital Technology Knowledge and Skills	3.72 $\pm$ 0.70	3.96 $\pm$ 0.66	3.88 $\pm$ 0.76	4.17 $\pm$ 0.59	9.112	0.000**
Digital Social Responsibility	3.68 $\pm$ 0.72	3.95 $\pm$ 0.66	3.82 $\pm$ 0.81	4.07 $\pm$ 0.64	8.194	0.000**

\*  $p < 0.05$  \*\*  $p < 0.01$

### 4.4. An Analysis of the Variations in Digital Literacy Among Rural Teachers Across Different Academic Stages

From the analysis presented in the table, it is evident that there are no significant differences in the digital literacy of rural teachers across different school stages concerning four key aspects: resource selection and utilization, evaluation, digital technology application, and ethical considerations ( $p > 0.05$ ). However, when examining professional development, notable differences emerge among teachers from vari-

ous school stages ( $F = 5.084$ ,  $p = 0.000$ ), as shown in Table 6. Specifically, high school teachers exhibited higher average scores compared to primary school teachers; similarly, those teaching in nine-year schools outperformed their primary counterparts. Furthermore, educators from other school stages also achieved higher average scores than primary school teachers. Additionally, high school teachers scored higher than junior high school instructors; likewise, nine-year school teachers surpassed junior high educators in terms of average scores while those from other educational levels also performed better than junior high school teachers.

**Table 6.** Results of the Differential Analysis of Academic Stages Among Rural Teachers.

	School Stages (Mean $\pm$ standard deviation)					<i>F</i>	<i>p</i>
	Primary School ( <i>n</i> =678)	Junior High School ( <i>n</i> =366)	Senior High school ( <i>n</i> =129)	Nine-year School ( <i>n</i> =29)	Others ( <i>n</i> =18)		
Professional Development	3.73 $\pm$ 0.69	3.71 $\pm$ 0.70	3.91 $\pm$ 0.69	4.10 $\pm$ 0.62	4.11 $\pm$ 0.58	5.084	0.000**
Digital Awareness	3.81 $\pm$ 0.68	3.81 $\pm$ 0.67	3.91 $\pm$ 0.67	3.90 $\pm$ 0.67	4.06 $\pm$ 0.64	1.271	0.279
Digital Applications	3.71 $\pm$ 0.74	3.72 $\pm$ 0.72	3.81 $\pm$ 0.77	3.72 $\pm$ 0.75	3.78 $\pm$ 0.65	0.596	0.666
Digital Technology Knowledge and Skills	3.75 $\pm$ 0.71	3.78 $\pm$ 0.71	3.88 $\pm$ 0.70	3.72 $\pm$ 0.75	3.94 $\pm$ 0.64	1.132	0.340
Digital Social Responsibility	3.71 $\pm$ 0.73	3.73 $\pm$ 0.74	3.91 $\pm$ 0.73	3.76 $\pm$ 0.69	3.89 $\pm$ 0.76	2.280	0.059

\*  $p < 0.05$  \*\*  $p < 0.01$

## 5. Discussion

### 5.1. The Limitations of Digital Awareness and the Transformation of Capabilities

According to a survey of rural teachers in the western region of Guangdong, China, the rural teachers in this study were found to be relatively good in digital awareness, but scored the lowest in digital application. It indicates that while rural teachers demonstrate positive attitudes towards digital awareness, willingness, and intent, they are generally perceived as "weak" when it comes to effectively utilizing digital technologies in their teaching practices. Conversely, Xie and Li suggested that teachers particularly struggle with digital awareness compared to other dimensions such as digital knowledge and skills, digital application, social responsibility related to technology use, and professional development [22]. This conclusion is closely linked to regional disparities in the development of information technology infrastructure within rural areas as well as the foundational level of individual teachers' digital competencies. The insufficient exposure to technology and lack of effective application experiences hinder teachers from developing a profound understanding of digital teaching and learning processes. Consequently, this limitation restricts their motivation to proactively enhance their digital literacy. In contrast to the findings presented in this study, Zhu reported that rural teachers achieved the highest scores on the dimension of "digital social responsibility" while scoring lowest on "digital application" [14]. Additionally, Yu et al. confirmed that rural teachers in Henan Province demonstrated a high level of "digital awareness" [23].

This study reveals that one of the paradoxical factors con-

tributing to rural teachers' heightened digital awareness yet diminished application is their prolonged exposure to a digitally underdeveloped practice environment. The educational context in which these rural educators operate is characterized by lower levels of digitization, a situation that hinders their ability to effectively translate digital awareness into practical teaching competencies. Concurrently, due to insufficient access to advanced digital equipment, while teachers have acquired a certain degree of theoretical knowledge, they are unable to fully realize the practical advantages that such technology can offer in an educational setting. Furthermore, the level of acceptance among rural teachers regarding the integration of new technologies into education is notably lower than that observed among their urban counterparts; this demographic tends to exhibit a passive attitude towards the implementation of new technologies within educational practices [24]. Another reason for this issue is the significant supply-demand imbalance in the implementation of digital literacy improvement programs for rural teachers. Existing research indicates that rural educators encounter challenges related to training, peer support, and technical assistance [4, 25]. Specifically, while China has provided policy support and established a relevant training curriculum system aimed at enhancing teachers' digital literacy, there exists a structural contradiction between this curriculum framework and the informatization infrastructure conditions of grassroots schools during its implementation. The absence of a systematic assessment regarding regional disparities in educational informatization development [26] has led to a considerable misalignment between the training content and the actual teaching and learning environments present in rural schools. This disconnect between theory and practice has resulted in a scenario where teachers may grasp fundamental concepts of digital teaching and learning but struggle to apply these concepts effectively due to insufficient targeted operational

guidance. Ultimately, this situation not only undermines the effectiveness of teachers' professional development but also diminishes the overall impact of educational investments.

The findings from the data analysis in this study indicate that the transformation of digital awareness and competence represents a primary challenge faced by rural teachers in their journey toward developing digital literacy. The evolution of digital literacy among rural educators has been characterized by an initial emphasis on cognition, while practical application lags behind. Although policy guidance and training initiatives have successfully heightened rural teachers' awareness regarding the significance of digital teaching, there remains a pressing need to enhance their ability to translate this awareness into effective teaching practices. From a practical standpoint, rural teachers encounter numerous obstacles when attempting to improve their capacity for applying digital technology. In many educational institutions, not only is there an insufficient quantity of digital equipment, but existing resources also suffer from issues such as outdated configurations and inadequate maintenance-factors that directly impede teachers' instructional efforts. Moreover, it is particularly noteworthy that current teacher training programs frequently adopt a "one-size-fits-all" approach. This methodology fails to adequately account for the varying levels of information infrastructure development across different regions and schools, leading to a disconnect between the training content provided and the actual needs experienced by educators. These inter-related factors collectively create a bottleneck that hinders advancements in digital literacy among rural teachers.

To address this issue, it is essential to implement a systematic approach that includes the establishment of a "customized" training mechanism and the development of suitable training courses tailored to the hardware conditions of schools in remote areas. Given the rapid advancements in digital technology, primary and secondary schools in these regions should prioritize infrastructure investment, particularly focusing on enhancing teaching terminals and network environments. Regional education management departments ought to create a sustainable support system for primary and secondary schools located in remote areas. This can be achieved by providing teachers with ongoing professional development opportunities through the formation of regional teaching and research communities as well as the implementation of school-based training programs. Only through a comprehensive strategy can we effectively assist rural educators in integrating digital technology into their instructional practices.

## 5.2. Hierarchical Differentiation of Digital Literacy Among Rural Teachers

Rural teaching positions show a significant stratification in digital literacy, with principals being much more digitally literate than regular teachers. The difference stems from the

variation in the roles and responsibilities of principals, section heads, and regular teachers. As decision makers, principals need to master digital management tools such as data analysis and smart office systems, which directly affects the school's IT investment. Section heads and middle-level cadres, on the other hand, need to implement the principal's digital policy, integrate digital resources, such as online lesson planning and teaching and research platforms, promote digital teaching in their subjects, and apply more focused teaching innovations. On the other hand, ordinary teachers are usually at the end of the implementation, only using basic multimedia courseware or online homework platforms, and the application of digital technology stays at the level of tools and lacks systematization.

The role of principals as school administrators and leaders necessitates enhanced digital awareness and capabilities to effectively drive the overall digital transformation of schools. In this context, China has bolstered the position of rural principals in spearheading the development of digital education in rural areas through policy support and training programs. In April 2012, the Ministry of Education, along with eight other departments, launched the "Strong Teachers in Basic Education for a New Era" initiative. This program is dedicated to training rural teachers and principals in less-developed regions of central and western China. It emphasizes the importance of exemplary teachers and principals serving as role models while implementing a five-year cycle under the "National Training Program," which aims to guide teacher training across all regions. Clearly, during the process of digital transformation within rural education, there has been a significant increase in opportunities for enhancing digital literacy among rural principals.

However, existing studies indicate that rural principals exhibit significant deficiencies in their ability to effectively apply digital technologies [19, 17, 27]. Specifically, a majority of rural principals demonstrate a low level of awareness regarding emerging smart technologies such as artificial intelligence, big data analysis, and cloud computing. Furthermore, they possess limited operational skills related to these technologies, which hinders the effective integration of cutting-edge innovations into essential school functions including instructional management, administrative operations, and home-school communication. Such capability deficiencies make it difficult for principals to accurately grasp the technology development trend and provide professional guidance to ordinary teachers in the process of leading the digital transformation of schools, which ultimately restricts the depth and effectiveness of the construction of educational informatization in schools.

From the perspective of role expectations, rural principals are supposed to exercise digital leadership, and through their own digital mindset and practical demonstration, they can drive ordinary teachers in rural schools to change their traditional concepts of education and work together to improve their digital literacy in order to adapt to the needs of educa-

tional and pedagogical changes in the digital era. Alsharija and Watters showed that teachers with administrative positions have the authority to organize change and deploy resources, and they tend to have a more pronounced influence on the organization [28]. However, the reality is that rural principals are generally caught up in administrative affairs and need to cope with a variety of trivial matters in the daily operation of the school. Therefore, the current situation that rural principals' administrative affairs are more important than their professional rights has led to the fact that principals lack sufficient time and energy to devote to digital competence enhancement, and it is also difficult for them to concentrate on thinking about how to use digital technology to promote the innovative development of their schools, which ultimately creates the practical dilemma of "wanting to do something, but not being able to do it". Such situation not only restricts the personal professional development of rural principals in digital literacy, but also slows down the overall process of digital transformation of rural education to a certain extent.

Rural teachers, as grassroots educators, are a key force in the digital transformation of education and must be digitally literate in order to adapt to the trend of digitalization of education. However, in this survey, the digital literacy level of rural teachers did not meet expectations, and their performance was significantly behind and at the lowest level compared with principals, section heads and middle-level leaders. The formation of this status quo is closely related to the fact that rural teachers have long been influenced by traditional educational concepts and empirical thinking. The traditional concept makes rural teachers lack the enthusiasm to actively explore the reform of education and teaching empowered by digital technology, and it is difficult for them to actively adapt to the development trend of digitalization of education. Further analysis of the results of this survey reveals that the age structure of the rural teacher group is aging, leading to a relative lack of acceptance and application of new technologies. Zhang et al. also confirmed in their study that rural villages are faced with the status quo of low teacher salaries, difficulty in career advancement, and trivial work [18]. These factors work together to become an important obstacle that restricts the digital literacy of ordinary teachers in the countryside.

### 5.3. Disparities in Professional Development Across Various Academic Stages

School environments and teaching characteristics of different school segments lead to uneven development of rural teachers in digital learning and training, as well as digital teaching research and innovation. In a survey of rural teachers' digital literacy in eastern, central, and western China, Song showed that elementary school teachers' digital literacy was higher than secondary school teachers' digital literacy [29]. However, this is different from the results of the current

survey with it, supporting the findings of Yu and Zhang [23]. Specifically, it was found that senior secondary level teachers demonstrated superior overall digital literacy, while primary and junior secondary level teachers displayed relatively lower levels. This discrepancy can be attributed to the differing teaching tasks and requirements associated with various educational segments. High school educators experience greater pressure to facilitate students' progression into higher education; consequently, their effectiveness in teaching increasingly relies on data analysis, online instruction and research methodologies, as well as intelligent teaching tools. As such, their needs for digital training and innovative practices are significantly heightened. In contrast, while junior high school teachers are also tasked with advancing to higher education, the impetus for digital teaching reform may be less pronounced than that observed in senior high schools. Consequently, some institutions continue to adhere predominantly to traditional teaching models, leading to lower professional development scores compared to those of senior high schools and nine-year schools. Elementary school teachers face relatively basic teaching content; thus, their digital applications primarily remain at a superficial level, such as courseware production and multimedia presentations. This situation is characterized by a notable lack of motivation for in-depth training and innovation. In nine-year schools-which encompass both primary and junior high education-teachers must adapt digital teaching strategies to accommodate students across various age groups. These institutions typically place greater emphasis on the comprehensive planning of educational informatization, resulting in a higher level of digital professional development among their educators.

The findings of this study further substantiate the conclusion that there exists a significant disparity in digital literacy among rural teachers across different geographical regions. Moreover, this disparity is closely associated with the level of support provided by schools. This observation aligns with the research conducted by Althubyani, which demonstrated that various factors influence teachers' levels of digital competence, with school support and training programs being pivotal among them [30]. Consequently, it is imperative for rural schools to offer systematic professional development programs for teachers, particularly focusing on training related to the application of digital technology. Such initiatives are essential for fostering both teachers' professional advancement and students' overall development.

Uneven training resources and policy support contribute to disparities in professional development among teachers at various school levels. Guillán-Gómez and Mayor-ga-Fernández demonstrated that insufficient teacher training exacerbates the digital divide among rural educators [21]. High schools typically receive greater emphasis in regional education informatization initiatives, resulting in increased access to advanced digital training opportunities, such as smart classrooms and big data precision teaching. In contrast,

the training provided for elementary school teachers tends to concentrate on fundamental skills. Nine-year schools benefit from more comprehensive support for digital teaching and research programs due to their broader educational scope, which facilitates teachers' professional growth. Conversely, rural junior high schools and elementary institutions face limited opportunities for their educators to engage in high-level digital training owing to resource constraints.

The disparities in the level of school informatization construction have a significant impact on the professional development of teachers across different educational stages. High schools and nine-year schools offer educators abundant opportunities for digital teaching and research, owing to their relatively advanced informatization infrastructures, which include smart classrooms and dedicated teaching and research platforms. In contrast, some rural elementary schools exhibit lagging informatization infrastructure that only fulfills basic multimedia teaching requirements, lacking an environment conducive to comprehensive digital training. Nonetheless, teachers in remote areas can still achieve notable advancements through the strategic utilization of digital resources. For instance, rural educators in Utopia County, Hunan Province have successfully implemented a thorough digital transformation of their teaching practices and research activities by leveraging various digital platforms. These include WPS 365 Education Edition, the West Teaching House Digital Teaching and Research Community Platform, the Wisdom Teaching Interactive Lecture Platform, the Academic Big Data Platform, as well as national initiatives such as the National Wisdom Education Platform for Primary and Middle Schools and the Ministry of Education's Collaborative Enhancement of Teaching and Research Communities Project. The practice shows that even in remote areas with relatively weak information technology infrastructure, teachers and students can achieve significant improvement in the quality of teaching and learning through the rational use of digital resources, thus narrowing the gap in digital professional development with other regions.

To narrow the digital divide between teachers of different academic grades, the Government should adjust its education policy and increase its investment in primary and junior secondary education, while encouraging social forces to participate in the balanced distribution of education resources. Schools should strengthen collaborations with other educational institutions to share digital teaching resources and best practices, thereby collectively advancing teachers' professional development. Additionally, rural schools must offer systematic professional development programs for teachers, particularly focusing on training related to the application of digital technology. This initiative will significantly bolster teachers' proficiency in utilizing digital tools, ultimately facilitating their professional growth as well as promoting student development.

## 6. Conclusion

The enhancement of teachers' digital literacy is a crucial competency for educators to effectively adapt to the evolving landscape of education. In developing countries and remote regions, teachers consistently face challenges stemming from inadequate infrastructure and limited training opportunities. The insufficient digital competence among teachers adversely impacts the effectiveness of educational digital transformation in these areas. The study elucidates the challenges encountered by rural teachers in enhancing their digital literacy in western Guangdong, China. The findings further substantiate that geographical disparities significantly influence the digital literacy of rural educators in China; specifically, the more remote a teacher's location, the poorer their performance across five dimensions of digital literacy. Notably, the primary challenge for rural teachers' improvement in digital literacy has transitioned from a lack of basic digital awareness to constraints related to transforming both awareness and capabilities—a phenomenon also observed in less developed regions worldwide. Rural educators face numerous obstacles when attempting to enhance their proficiency in applying digital technology, which not only impacts their teaching practices but also constrains their professional development.

Moreover, there exists a pronounced differentiation within the hierarchy of rural teachers' digital literacy levels, with overall proficiency failing to meet anticipated benchmarks. In comparison to principals, section heads, and middle leaders, rural teachers exhibit significantly lower performance levels regarding digital literacy—ranking at the lowest tier. Additionally, rural principals have not fully leveraged their potential for effective digital leadership during technological advancements; this shortcoming has adversely affected the collective enhancement of rural teachers' digital.

The study also identified significant disparities in the professional development of rural teachers across different school years. This phenomenon further substantiates the notion that an uneven distribution of training resources and policy support contributes to the widening digital divide among rural educators. Consequently, to foster a comprehensive enhancement of digital literacy among rural teachers, it is imperative to optimize the allocation of training resources, bolster policy support, and strengthen the digital leadership capabilities of rural principals. This should be approached through an analysis of geographic differences, variations in school segments, and hierarchical differentiation, with the ultimate goal being the digital transformation and high-quality development of rural education.

Thus, this research provides a novel empirical foundation for mapping the landscape of rural teachers' digital literacy in China. Although the study sample is limited to a specific group of rural teachers from western Guangdong province, it reveals distinctive characteristics and typical conditions regarding their digital literacy within this region. The issues

and trends highlighted in this investigation exhibit a degree of generalizability and representativeness. As such, the findings from this study serve as a valuable reference for conducting more extensive research on rural teachers' digital literacy in other regions as well as for formulating strategies aimed at enhancing digital literacy overall.

## Abbreviations

DigCompEdu	Digital Competencies for Educators
ANOVA	Analysis of Variance
MOE	Ministry of Education of the People's Republic of China
KMO	Kaiser-meyer-olkin

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## Author Contributions

**Lin Wang:** Methodology, Writing - original draft, Writing - review & editing

**Yanfen Huang:** Data curation, Investigation

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## Conflicts of Interest

The authors declare no conflicts of interest.

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