

The Dual-Path Approach of Motivation and Assessment Competence: An Integrated Model for Digital Literacy Development Among Rural Teachers

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Against the backdrop of digital technology significantly advancing educational modernization, enhancing digital literacy among rural teachers has become pivotal in promoting educational equity and improving teaching quality. However, existing research largely adopts a technical training perspective, neglecting the interplay between teacher motivation and classroom assessment literacy—a fundamental element of instructional practice. This gap has led to a pronounced disconnect between theoretical knowledge and its practical application in the development of rural teachers' digital competencies. This study aims to develop and validate an integrated model to examine how teacher motivation and assessment competence jointly influence the development of digital literacy through dual pathways. A sample of 345 rural primary and secondary school teachers from western Guangdong Province, China, was surveyed, and structural equation modeling was employed to test the proposed theoretical model. The results indicate a significant positive direct effect of teacher motivation on digital literacy, as well as a synergistic enhancement effect between extrinsic and intrinsic motivation. In the assessment domain, educational evaluation and progress monitoring act as catalysts for enhancing digital literacy, whereas instructional decision-making exerts an inhibitory effect, and the role of identifying special educational needs remains statistically insignificant. The findings confirm that the sustained development of rural teachers' digital literacy must extend beyond the narrow confines of technical training. Through systematic design of reflective tasks and the provision of targeted assessment scaffolding, a paradigm shift from passive knowledge transmission to autonomous professional growth can be achieved. The dual-path model proposed in this study provides actionable insights for addressing deep-seated challenges in the digital transformation of rural education.

Keywords: digital literacy, intrinsic motivation, extrinsic motivation, classroom-based assessment competence, rural teachers

Introduction

Amidst the rapid advancement of digital technologies, digital literacy has become an essential professional competency for educators (Cabero et al., 2020; Saripudin et al., 2019). In recent years, the Chinese government has placed considerable emphasis on enhancing teachers' digital literacy, providing substantial institutional and policy support to advance this goal. In 2021, the Cyberspace Administration of China (CAC) issued the Action

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Outline for Enhancing National Digital Literacy and Skills, which explicitly identifies digital literacy as a fundamental attribute for citizens in the digital era (CAC, 2021). Particularly in education, a joint policy document released in 2025 by nine ministries—including the Ministry of Education—highlighted the urgent need to accelerate the digital transformation and upgrading of the education system. As a result, improving teachers' digital literacy has emerged as a critical strategic priority in China's educational development.

However, the enhancement of digital literacy among rural teachers in China continues to face structural challenges. Practical constraints, such as inadequate digital infrastructure in rural schools and a scarcity of professional development resources for teachers (Wu et al., 2022; Wu & Wang, 2024), directly hinder both the practical competence and motivational engagement of rural educators in utilizing digital technologies. Consequently, advancing the digital transformation of rural education in Guangdong Province, China, ultimately depends on improving the digital literacy of rural teachers (Wu et al., 2022). Without fundamentally addressing rural teachers' capacity to integrate digital technologies into pedagogical practices, the sustainable development of digital education will remain unattainable, irrespective of the scale of infrastructure investment.

Current research on the digital literacy deficits of rural educators predominantly focuses on resource scarcity or insufficient motivation, often neglecting the critical role of foundational classroom assessment competence in instructional practice. In reality, classroom assessment—particularly data-informed evaluative practices—serves as a vital bridge between pedagogical intentions and actual teaching behaviors (Blumenthal et al., 2021; Wilcox, Fernandez Conde, & Kowbel, 2021). However, as demonstrated by Silva et al. (2021), assessment practices in most schools remain largely summative and screening-oriented. Consequently, teachers rely heavily on personal experience in key instructional activities such as student evaluation, progress planning, and the identification of special learning needs, resulting in assessment outcomes that inadequately support subsequent improvement processes. It suggests that educators struggle to harness the inherent potential of digital technologies in their teaching practices, thereby hindering the effective development of their digital literacy. The role of foundational classroom assessment competence in fostering teachers' digital literacy has yet to receive adequate attention or systematic investigation in existing literature.

This study aims to develop a dual-path model that integrates teacher motivation, classroom assessment literacy, and digital literacy. The model conceptualizes teachers' extrinsic and intrinsic motivation as interrelated dimensions and emphasizes the mediating role of classroom assessment ability, thereby providing a comprehensive model for understanding the development of digital literacy among rural educators. Theoretically, the findings are expected to clarify the underlying mechanisms of digital literacy development and provide empirical support for relevant theoretical frameworks. Practically, the results may inform the design of professional development programs for rural teachers, assisting educational administrators in formulating holistic strategies that simultaneously promote motivational enhancement and competency development.

Literature Review

Teachers' Digital Literacy (TDL)

Educators must continuously enhance their digital competencies and proactively integrate digital technologies into instructional practices, while fostering innovative mindsets and a commitment to educational reform. These efforts are aimed at substantially improving teaching quality and pedagogical outcomes. To provide systematic guidance for the development of these competencies, the Ministry of Education of China (MOE) promulgated the Teacher Digital Literacy standard (MOE, 2023), which delineates essential digital capabilities—including

information acquisition, processing, utilization, management, and evaluation—as well as the comprehensive literacy required to identify, analyze, and resolve problems in teaching practice. This standard establishes five core dimensions for assessing teachers' digital literacy: digital awareness (DA), knowledge and skills in digital technology (KSDT), digital application (DA), digital social responsibility (DSR), and professional development (PD).

As frontline educators, rural teachers face significant challenges stemming from limited digital infrastructure and scarce professional resources. Serving as a crucial force in China's basic education system, they bear substantial responsibility for promoting educational equity and ensuring equitable access to quality schooling. Their role is particularly vital in advancing digital education initiatives and interrupting the intergenerational transmission of poverty and marginalization. Nevertheless, educational researchers acknowledge that numerous challenges persist in implementing programs designed to enhance digital literacy among rural educators (Wang, Tigelaar, & Admiraal, 2022; Wu et al., 2022). Therefore, establishing effective support pathways to strengthen the digital literacy of rural teachers is essential to enable them to confidently navigate the challenges and capitalize on the opportunities presented by the ongoing digital transformation of education.

Teacher Motivation (TM)

Teacher motivation refers to the psychological construct encompassing intrinsic drivers and extrinsic influences that motivate individuals to enter the teaching profession, sustain long-term engagement in pedagogical work, and continuously improve their instructional practices (Rothinam, Samuel, Vengasalem, & Naidu, 2024). It fundamentally shapes educators' initial career choices, the level of commitment to teaching, and the ways in which they persist and refine their instructional methodologies throughout their professional development. Teacher motivation comprises two primary dimensions: intrinsic and extrinsic motivation. Intrinsic motivation (IM) arises from educators' inherent interest in educational activities, their cognitive and affective identification with teaching (often described as a “sense of vocation”), and the satisfaction derived from student growth, the intrinsic enjoyment of teaching, and autonomy in professional decision-making (Albishi, 2021). Extrinsic motivation (EM), by contrast, is distinct from the act of teaching itself and relates to external rewards such as remuneration, professional titles, awards, social recognition, and familial considerations (Zhang & Deng, 2020; Albishi, 2021).

However, rural teachers in China face significant practical challenges in developing digital literacy. Cui and Xu (2024) pointed out that these educators are situated in the “peripheral zones” of digitalization, where information isolation, fragmented knowledge structures in digital technology, and limited technical experience contribute to a lack of recognition of digital teaching methods. Wu and Wang (2024) and Zhao (2024) observed that the rural teaching workforce in China generally exhibits low motivation, with most teachers demonstrating reluctance to enhance their digital literacy. The already demanding teaching loads and administrative responsibilities further undermine their intrinsic motivation to develop digital competencies (Zhang et al., 2023).

EM plays a significant role in the development of teachers' digital literacy in rural educational contexts. School-based support factors account for 59.4% of the variance in digital resource allocation among rural educators (Wu et al., 2022). Institutional support and professional development opportunities constitute key determinants influencing the digital competency levels of rural teachers (Althubyani, 2024). However, digital infrastructure in rural schools remains underdeveloped, characterized by inadequate digital facilities, unstable internet connectivity, low-quality instructional hardware, and insufficient technical maintenance (Padilla

Rodríguez, Armellini, & Traxler, 2021; Guillén-Gámez & Mayorga-Fernández, 2022). These material constraints hinder teachers' ability to translate theoretical knowledge of digital technologies into practical application (Zhu, 2024). Concurrently, rural teachers are often required to deliver multidisciplinary instruction and manage heavy administrative workloads, leaving limited time for technological learning and skill development (Zhao, 2019), which further impedes the advancement of their digital literacy (García, García-Carmona, Trujillo Torres, & Moya Fernández, 2021). Consequently, even in the presence of intrinsic motivation, the lack of adequate external motivational support creates structural barriers to the development of teachers' digital literacy.

Classroom-Based Assessment Competence of Teachers

Classroom-Based Assessment (CBA) competence constitutes a core professional competency for educators and reflects an essential dimension of teacher professionalization. Zhao (2004) conducted pioneering work by analyzing CBA from the perspective of assessment subject relationships and, incorporating the characteristics of China's educational development at the time, identified student-centeredness, teacher leadership, and mutual teacher-student benefit as its three defining features. She argued that CBA is an integral component of the teaching process. Wang (2021) further clarified the interdependent relationship between assessment quality and instructional quality, conceptualizing CBA as a process-oriented, closed-loop mechanism that informs instructional adjustments, enhances student learning, and supports teacher development. Jungjohann and Gebhardt (2023), integrating the characteristics of the digital era, have expanded the conceptual scope of CBA. They emphasized that teachers should employ both formative and summative assessment tools—appropriately adapted to disciplinary content and student diversity—to transform CBA from mere “outcome evaluation” into a data-informed decision-making system. This system facilitates instructional planning, identifies learning difficulties, monitors academic progress, and ultimately strengthens teachers' professional capacity to support individualized student development.

The majority of rural Chinese teachers acknowledged the value of “using assessment to enhance teaching”; however, in actual teaching practice, evaluation typically occurs after instruction rather than being integrated throughout the entire teaching process. Assessment methods are often limited to summative measures such as unit tests and final grades (Cui, 2022). As early as 2015, Chinese scholar Wang (2015) identified deficiencies in the classroom assessment practices of rural educators in China. The time rural teachers devote to assessment falls significantly below the international benchmark—approximately one-third of classroom time allocated for evaluation—with diagnostic and regulatory functions receiving insufficient attention. X. C. Li, Qi, and F. H. Li (2021) investigated the CBA capabilities of 312 teachers across 46 rural schools in China and found that rural educators frequently lack access to timely and visualized data on student progress during instruction. Even when such data are available, most teachers lack the skills to interpret graphical progress representations, thereby impeding their ability to adjust teaching strategies based on data-driven insights. This finding is consistent with the research of Jungjohann and Gebhardt (2023). Li (2022) further emphasized that TDL among rural teachers provides real-time evidence and tools to enhance instructional monitoring capabilities, while instructional monitoring competence, imbues TDL with educational context and value orientation.

Therefore, although rural teachers possess CBA capabilities, in practice they face a practical challenge characterized by limited assessment and data analysis skills, often confined to a single assessment type. Rural teachers not only lack the ability to collect and interpret visualized data, but also struggle to transform assessment data into actionable instructional decisions. This phenomenon of “data insensitivity” constrains the enhancement

of classroom teaching quality, reflecting the overall underdevelopment of digital literacy among rural educators. At the same time, it further indicates that foundational classroom assessment competence is closely associated with teachers' digital literacy.

Materials and Methods

Instrument

The research instrument consists of three principal components. The digital literacy component was developed in accordance with the "Digital Literacy for Teachers" (Ministry of Education of China, 2023). The teacher motivation component integrates dimensions of internal and external motivation, grounded in the conceptual framework of the hybrid learning motivation model proposed by Ibrahim and Nat (2019). The CBA component was adapted from the core measurement dimensions established by Jungjohann and Gebhardt (2023). To ensure greater contextual alignment with the teaching realities of educators in remote areas of western Guangdong, China, the research team implemented localized modifications to item phrasing and dimensional configuration based on findings from a pilot study and expert review, thereby enhancing the cultural relevance and measurement validity of the instrument. A five-point Likert scale, ranging from "strongly disagree" to "strongly agree", was employed to measure participants' agreement levels with each statement, yielding robust and reliable data to support the examination of strategies through which rural teachers can improve their digital literacy.

Data Collection

Data collection for this study began in November 2023 as part of the "Basic Research Project on Digital Construction in Rural Schools of Western Guangdong Province" organized by Zhaoqing University, ensuring systematic implementation through institutional support. The initial draft of the questionnaire was completed in May 2024 and subsequently underwent expert review in June of the same year, during which three specialists in education and educational technology evaluated the reliability of its structure and item content. Their feedback informed revisions that led to the development of a refined second version. A pilot test was conducted in October 2024 with 30 teachers from rural primary and secondary schools, who participated in a trial administration of the instrument. Qualitative feedback and response patterns were analyzed to improve item clarity, content relevance, and linguistic precision, resulting in the final version of the formal questionnaire. The survey was then administered online to teachers across rural schools in western Guangdong Province between April and May 2025, yielding 345 valid responses, which constitute the analytical dataset for this study.

Participant Information Description

A total of 345 valid questionnaires were collected in this survey, with participants primarily consisting of rural teachers from the western region of Guangdong Province. Regarding demographic characteristics, the gender distribution is well balanced, with males accounting for 51.01% and females for 48.99%. In terms of teaching experience, the sample is predominantly composed of experienced educators. Specifically, 50.43% of the respondents have 16 to 30 years of teaching experience, 24.64% have 7 to 15 years, and those with less than six years of experience constitute less than 10% of the sample, reflecting a certain degree of aging trend in the teaching staff in this region.

With regard to school type, 78.26% of the participants are from village schools and 21.74% from township schools, indicating that the sample is highly representative of rural educational settings. In terms of educational

level, teachers from rural junior high schools slightly outnumber those from rural primary schools, accounting for 53.04% and 46.38%, respectively. Teachers from rural senior high schools and nine-year integrated schools constitute a very small proportion. Regarding professional title distribution, full-time classroom teachers account for 71.59%, middle-level administrators represent 17.39%, and school-level leaders make up only 9.57%. In terms of teaching subject areas, approximately 71.59% of the teachers instruct core subjects such as Chinese, mathematics, and English; about 14.78% teach integrated humanities subjects including politics, history, geography, and biology; and the remaining 13.63% teach specialized subjects such as information technology, art, and physical education. This distribution suggests that the sample in DL study is predominantly composed of main-subject teachers. Overall, the survey effectively encompasses the mainstream teaching population in rural primary and secondary schools in western Guangdong Province. The sample demonstrates representativeness across key dimensions, including teaching experience, educational stage, and subject composition, thereby supporting the practicality and validity of subsequent DL research.

Results

Reliability and Validity Analysis

The results presented in Table 1 indicate that the 345 valid questionnaires assessing digital literacy demonstrate high internal consistency reliability, both at the overall scale level and across individual dimensions. The overall Cronbach's α coefficient is 0.977, exceeding the recommended threshold of 0.90 for excellent reliability as proposed by Wu (2021). The α values for the four main dimensions—digital literacy, external motivation, internal motivation, and classroom-based assessment ability—range from 0.807 to 0.957, all surpassing the widely accepted criterion of 0.80 for social science measurement instruments. Within the Teachers' Digital Literacy (TDL) dimension, the sub-dimensions of Digital Technology Knowledge and Skills (DTKS) ($\alpha = 0.941$), Teacher-Technology Interaction (TTI) ($\alpha = 0.957$), and Teacher Attitudes and Beliefs (TAB) ($\alpha = 0.945$) exhibit particularly strong reliability, indicating stable and consistent measurement properties. The reliability coefficients for Teaching Workload (TWL) ($\alpha = 0.826$) and Educational Assessments (EdA) ($\alpha = 0.807$) are relatively lower but still exceed the minimum acceptable threshold of 0.70 and remain close to the robustness benchmark, thus falling within an acceptable range as shown in the table. Overall, the survey data demonstrate high reliability and quality, providing a solid empirical foundation for subsequent analyses of the complex relationships among rural Teachers' Digital Literacy (TDL), Classroom-Based Assessment (CBA), and teacher motivation (TM).

Table 1

Results of Reliability Analysis

Primary dimension	Secondary dimension	Item number	Sample size	Cronbach's α coefficient
Teachers' Digital Literacy (TDL)	Professional development (PD)	5	345	0.907
	Digital awareness (DA)	3	345	0.922
	Digital application (DApp)	3	345	0.909
	Digital Technology Knowledge and Skills (DTKS)	3	345	0.941
	Digital social responsibility (DSR)	3	345	0.902
	Teacher-Technology Interaction (TTI)	3	345	0.957
Extrinsic motivation (EM)	Teaching Workload (TWL)	4	345	0.826
	School environment (SE)	4	345	0.930
	Teacher-student interaction (TSI)	3	345	0.921

Table 1 to be continued

Intrinsic motivation (IM)	Teacher Attitudes and Beliefs (TAB)	4	345	0.945
	Teacher continuing learning (TCL)	4	345	0.939
	Willingness to implement digital teaching (WIDT)	4	345	0.929
	Willingness to adopt digital resources (WADR)	3	345	0.915
	Instructional decision-making (IDM)	5	345	0.878
Classroom-Based Assessment (CBA)	Educational Assessments (EdA)	7	345	0.807
	Identification of Special Educational Needs (IdSEN)	5	345	0.881
	Progress monitoring (PoM)	7	345	0.892
Total		70	345	0.977

Validity testing aims to determine whether research instruments or methods accurately measure the intended construct, thereby ensuring the scientific rigor and effectiveness of the survey tools employed. The analysis results indicate that the overall KMO value for the scale is 0.937 (Table 2), which exceeds the recommended threshold for sampling adequacy. Exploratory factor analysis further confirmed the suitability of the data structure. The KMO values for the multi-dimensional theoretical framework range from 0.766 to 0.961, all above the acceptable criterion of 0.60, and Bartlett's test of sphericity was statistically significant ($p < 0.001$), indicating strong inter-item correlations. These findings suggest that the dataset is suitable for factor extraction and supports meaningful interpretation. To assess validity comprehensively, a multi-indicator integration approach was adopted, with results summarized in Table 3. The average variance extracted (AVE) was used to evaluate the extent to which each construct captures its indicator variance. For the three main dimensions—TDL, TM, and CBA—the cumulative variance explained after rotation reached 84.994%, 72.580%, and 72.580%, respectively, all surpassing the 50% benchmark. This indicates that the selected factors effectively represent the underlying constructs and that the questionnaire exhibits a clear and coherent structure. Collectively, these results demonstrate good construct validity, providing a solid foundation for subsequent data analysis.

Table 2

KMO and Bartlett's Test Results

KMO value		0.937
Bartlett's Test of Sphericity	Approximate chi-square	30,029.405
	df	1,953
	<i>p</i> value	0.000

Table 3

Validity Analysis Results

Items	Eigen (initial)	% of variance (initial)	Cum. % of variance (initial)	Eigen (rotated)	% of variance (rotated)	Cum. % of variance (rotated)	KMO value	Bartlett's Test of Sphericity	df	<i>p</i> value
DTKS	11.746	69.095%	69.095%	3.778	22.224%	22.224%	0.959	6,387.264	136	0.000
DA	1.164	6.845%	75.940%	3.406	20.034%	42.258%				
DApp	0.575	3.381%	79.321%	2.839	16.702%	58.959%				
DSR	0.494	2.904%	82.225%	2.776	16.327%	75.286%				
PD	0.471	2.769%	84.994%	1.650	9.708%	84.994%				
IM	19.527	67.333%	67.333%	14.663	50.563%	50.563%	0.961	12,979.611	406	0.000
EM	1.521	5.246%	72.580%	6.385	22.016%	72.580%				
PoM	12.840	51.359%	51.359%	6.852	27.408%	27.408%				
IDM	3.193	12.771%	64.130%	5.350	21.399%	48.807%	0.766	33,262.064	300	0.000
IdSEN	3.053	12.211%	76.341%	5.273	21.092%	69.899%				
EdA	2.010	8.042%	84.383%	3.621	14.483%	84.383%				

Development of a Model for Enhancing Rural Teachers' Digital Literacy

This study employs the structural equation modeling (SEM) approach to examine the hypothesized relationship model among teaching motivation (TM), Classroom-Based Assessment (CBA), and Teachers' Digital Literacy (TDL) in rural educational contexts. As shown in the model results (Table 4), the absolute fit index $\chi^2 = 6.704$ ($p = 0.569$) is non-significant, indicating no statistically significant discrepancy between the observed covariance structure and the proposed model. Additional fit indices further support model adequacy: The chi-square to degrees of freedom ratio (χ^2/df) is 0.838 (< 3), RMSEA = 0.000 (< 0.05), GFI = 0.997 (> 0.90), and SRMR = 0.016 (< 0.05). These values meet or exceed conventional thresholds for model fit, reflecting minimal estimation error and strong reproducibility. Collectively, these results demonstrate that the SEM model exhibits excellent fit to the data, satisfying all standard criteria and thereby supporting the validity of the proposed structural relationships among TM, CBA, and TDL among rural teachers.

Table 5 presents the results of the structural equation modeling (SEM) analysis. A significant and consistently positive path was found between rural teachers' motivation and their digital literacy. EM exerts a significant positive predictive effect on IM ($\beta = 0.782$, $z = 23.268$) and on TDL ($\beta = 0.522$, $z = 9.331$). IM, in turn, has significant positive effects on EM ($\beta = 0.540$, $z = 8.931$), TDL ($\beta = 0.271$, $z = 4.817$), and CBA ($\beta = 0.173$, $z = 4.745$). Furthermore, CBA demonstrates a significant negative predictive effect on IM ($\beta = -0.233$, $z = 4.248$). All path coefficients were statistically significant at the $p < 0.01$ level, indicating that motivational factors play a critical role in fostering TDL development among rural teachers. Both EM and IM serve as important direct drivers in enhancing rural teachers' TDL. The interplay between internal and external motivations can foster a virtuous cycle that supports sustained motivation development among rural teachers.

Table 4

Model Fit Indicators

Common indicators	χ^2	df	p	χ^2/df	GFI	RMSEA	RMR	CFI	NFI	NNFI
Judgment criteria	-	-	> 0.05	< 3	> 0.9	< 0.10	< 0.05	> 0.9	> 0.9	> 0.9
Value	6.704	8	0.569	0.838	0.997	0.000	0.006	1.001	0.996	1.003
Other indicators	TLI	AGFI	IFI	PGFI	PNFI	PCFI	SRMR			
Judgment criteria	> 0.9	> 0.9	> 0.9	> 0.5	> 0.5	> 0.5	< 0.1			
Values	1.003	0.989	1.001	0.222	0.284	0.286	0.016			

Notes. Default Model: $\chi^2(28) = 1,510.759$, $p = 1.000$, AIC = 55.961, BIC = 163.580.

Table 5

Summary of Model Regression Coefficients

X	→	Y	Unstandardized coefficients	SE	Z (CR value)	p	Standardized coefficient (β)
EM	→	IM	0.787	0.034	23.268	0.000	0.782
EM	→	DL	0.511	0.055	9.331	0.000	0.522
IM	→	DL	0.264	0.055	4.817	0.000	0.271
IM	→	EM	0.376	0.042	8.931	0.000	0.540
IM	→	CBA	0.106	0.022	4.745	0.000	0.173
CBA	→	IM	0.562	0.132	4.248	0.000	0.233

Note. indicates path influence relationships.

In addition, rural teachers' CBA competence does not have a direct and statistically significant effect on the improvement of TDL. However, it plays a crucial indirect role by exerting a significant positive influence on IM ($\beta = 0.233$). When teachers master the fundamental skills required to evaluate digital courses, they become more confident and experience a greater sense of control, which in turn enhances their intrinsic motivation to integrate digital technology into teaching. This increased motivation ultimately drives them to acquire and master additional digital competencies, thereby improving their overall professional quality. While CBA competence is not an end in itself, it serves as a key component in the processes of "empowerment" and "capability enhancement". So far, this study has established a model for enhancing digital literacy among rural teachers, as illustrated in Figure 1.

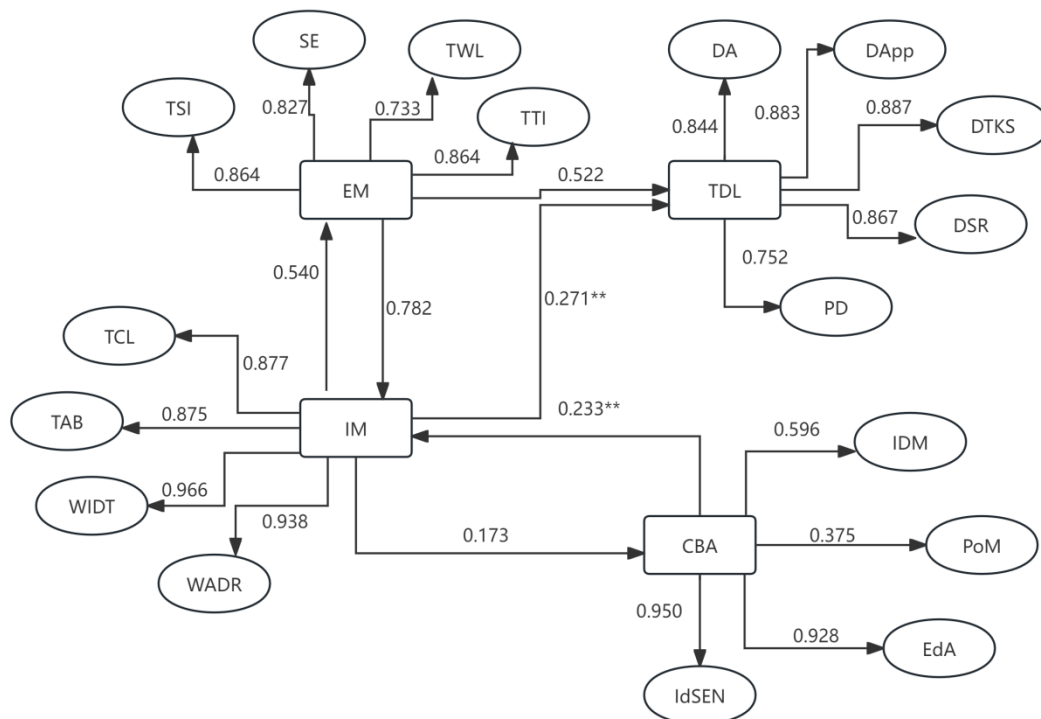


Figure 1. Model for enhancing rural teachers' digital literacy.

Regression Analysis of the Four Dimensions of CBA and TDL Dimension

Based on the regression analysis results, the influence of the four dimensions of CBA on the development of TDL exhibits significant variation, as illustrated in Figure 2. The data indicate that instructional decision-making (IDM) exerts significant negative effects across all four dimensions ($\beta = -0.414$ to -0.278 , $p < 0.001$), with the strongest impact observed on digital technology knowledge and skills ($\beta = -0.414$). This suggests that teachers' current instructional decision-making capacity is imposing a notable constraining effect on the development of their digital literacy.

In contrast, Educational Assessment (EdA) and progress monitoring (POM) demonstrate consistent positive effects. Progress monitoring exhibits the highest predictive efficacy for digital social responsibility ($\beta = 0.305$, $p < 0.001$), whereas Educational Assessment (EdA) has the strongest predictive effect on mastery of Digital Technology Knowledge and Skills (DTKS) ($\beta = 0.242$, $p < 0.001$). The standardized regression coefficients for EdA range from 0.144 to 0.242 ($p < 0.05$), and for progress monitoring (PoM), from 0.223 to 0.305 ($p < 0.001$). These findings indicate that both dimensions serve as positive contributors to the development of TDL.

It is noteworthy that the ability to Identification of Special Educational Needs (IdSEN) did not achieve statistical significance across all analyses ($\beta = -0.027$ to 0.060 , $p > 0.05$), indicating that this dimension currently has no significant impact on teachers' digital professional development. Furthermore, with respect to the overall model, all regression models met the significance criteria ($F = 5.869$ - 10.354 , $p < 0.001$), and the coefficient of determination (R^2) ranged from 6.5% to 10.9%, demonstrating that the model as a whole exhibits acceptable explanatory power.



Figure 2. Heatmap of standardized regression coefficients.

Notes. The colors indicate the direction and magnitude of the effects, with green denoting positive influences and red denoting negative influences. The values represent standardized regression coefficients (Beta). *** $p < 0.001$, ** $p < 0.01$, * $p < 0.05$.

Integration Model

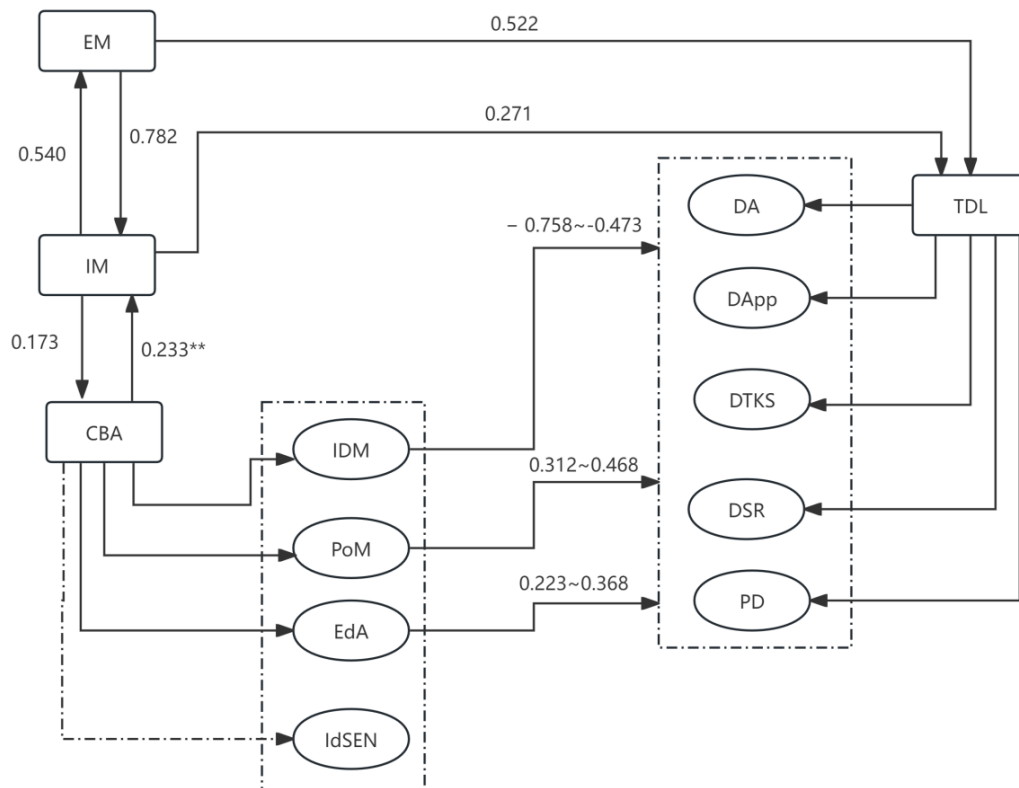


Figure 3. Dual-path model for enhancing the digital literacy of rural teachers (standardized parameter estimates).

The SEM results indicate that CBA positively and significantly predicts IM ($\beta = +0.233$) and indirectly enhances the digital literacy of rural teachers through this motivational pathway. However, the regression findings reveal that this overall effect stems from heterogeneous interactions among the internal dimensions. Specifically, EdA and POM exhibit robust and significant positive effects across all sub-dimensions of TDL, namely, DA, DApp, DTKS, DSR, and PD. These results demonstrate that strong CBA competence contributes positively to the development of digital literacy among rural teachers. In contrast, IDM exerts a significant negative impact across all sub-dimensions, representing a suppressive pathway. The ability to IdSEN shows no statistically significant effect on any sub-dimension. The data uncover the underlying mechanism of CBA competence; when treated as a monolithic construct, its positive and negative effects may offset each other, potentially leading to biased policy recommendations or intervention strategies. So far, this study has established a dual-path model for promoting digital literacy development among rural teachers, as illustrated in Figure 3.

Discussion

An Integrated Model for Enhancing Rural Teachers' Digital Literacy

Based on the empirical analysis of the structural equation model, this study developed and validated a dual-path model that elucidates the underlying mechanism of digital literacy formation among rural teachers, as illustrated in Figure 4. The model identifies teachers' intrinsic and extrinsic motivation as its foundational elements, which exhibit a significant bidirectional reinforcing relationship. EM enhances the activation and sustainability of IM, while robust IM prompts teachers to actively pursue and engage with external motivational sources. This reciprocal interaction serves as the dynamic foundation for the development of digital literacy.

The first path can be characterized as the motivation-driven direct pathway. As illustrated in Figure 4, both extrinsic and intrinsic motivation exert a strong direct influence on the enhancement of teachers' digital literacy ($EM/IM \rightarrow TDL$, strong direct effect). Notably, the model captures key characteristics of the rural educational context. EM demonstrates a substantial and direct driving force on digital literacy development. In rural schools, where resources and infrastructure are relatively limited, effective external incentives and institutional support play an indispensable role in initiating and sustaining teachers' use of digital technologies. At the same time, IM exerts a consistent and direct positive effect on digital literacy, reflecting the enduring impact of teachers' internalized professional commitment and enthusiasm. This pathway underscores that improving digital literacy necessitates both "external support" and "internal drive", which jointly constitute the most immediate and influential mechanism.

The second path is the practice-activated migration pathway. This path demonstrates that motivation, particularly IM, indirectly facilitates the development of digital literacy through the mediating role of CBA competence. CBA competence is manifested across four dimensions: IDM, PoM, EdA, and IdSEN. By applying digital technologies to proactively address assessment demands in authentic teaching contexts, teachers gradually acquire relevant technical skills through engagement in real-world tasks, thereby enabling the progressive development of their digital literacy. This pathway highlights that CBA competence serves as a critical mediating mechanism through which motivation is translated into practical teaching capability.

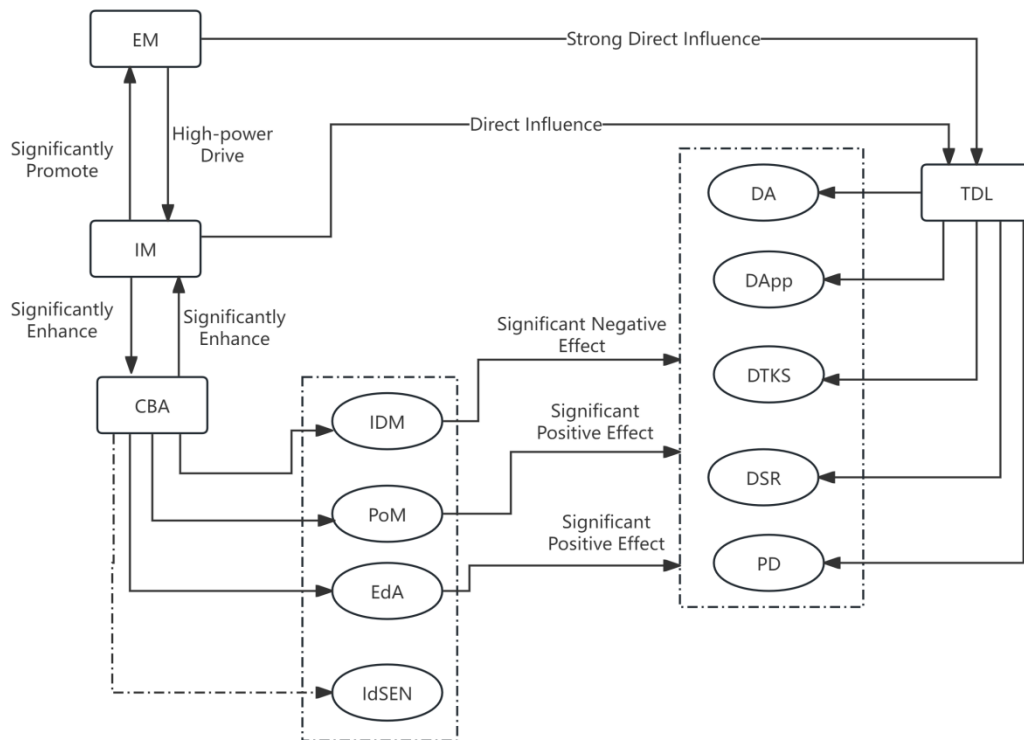


Figure 4. A dual-path model of digital literacy development among rural teachers (explanation of path relationships).

The Direct Driving Effect of Motivation on Digital Literacy

The motivational factors (IM and EM) of rural teachers also show a stable positive correlation with the development of digital literacy. From the perspective of path coefficients, EM shows a strong direct promoting effect on digital literacy ($\beta = 0.522$), while IM also has a stable positive impact on digital literacy ($\beta = 0.271$). This finding echoes the qualitative research conclusion conducted by Albishi (2021) in Saudi Arabia, which holds that teachers' intrinsic motivation is the main driving force influencing their continuous participation in classroom teaching without any material or honor rewards, as well as their persistent exploration and use of digital technologies to complete teaching tasks. This can directly promote the development of teachers' digital literacy.

Second, the findings of this study support the self-determination theory proposed by Ryan and Deci (2000), which posits that motivation—rooted in the satisfaction of psychological needs—serves as an intrinsic driver for individual competence development. Consistent with this perspective, Scherer, Siddiq, and Tondeur (2019) empirically demonstrated that external incentives are a key factor in promoting teachers' adoption of new technologies. Furthermore, Tondeur et al. (2023) emphasized that digital literacy does not develop in isolation from teaching practice; rather, it is closely tied to specific instructional contexts and professional development trajectories. Consequently, the motivational influence on digital literacy is fundamentally manifested in its capacity to encourage teachers to consistently apply and reflect upon digital tools within authentic classroom settings.

The Interactive Enhancement Effect of Extrinsic and Intrinsic Motivation

A close interactive relationship exists between extrinsic and intrinsic motivation. Rather than being mutually exclusive, the two forms of motivation exhibit a dialectical and mutually reinforcing dynamic. This study, through structural equation modeling, reveals that extrinsic and intrinsic motivation are reciprocally influential.

EM exerts a significant positive effect on IM ($\beta = 0.782$), and conversely, IM also significantly enhances EM ($\beta = 0.540$). These findings underscore the systemic and reciprocal nature of motivational processes.

From the perspective of practical mechanisms, appropriate external support facilitates the development of IM. When schools provide teachers with adequate digital resources, systematic training, and well-designed incentives, such support not only encourages the direct use of digital technologies but, more importantly, enhances teachers' sense of professional self-worth and belonging, thereby increasing their interest in digital teaching (Wu et al., 2022). This aligns with self-determination theory, which posits that external conditions can foster internal motivation by satisfying individuals' basic psychological needs (Ryan & Deci, 2000).

In addition, the intrinsic professional motivation and passion of teachers indirectly affect the characteristics of their external motivational response behavior towards teachers. Educators with a strong sense of professional mission are more likely to recognize and leverage the developmental opportunities provided by external incentives (Albishi, 2021), and to transform institutional support into effective resources for their own professional growth. This suggests that highly motivated teachers are better able to shape a conducive external environment for their development.

This bidirectional enhancement effect is particularly evident in the development of digital literacy among rural teachers. External support provides a catalyst for teachers to engage in digital teaching, while the sense of achievement derived from digital education strengthens their intrinsic motivation, thereby creating a cyclical and progressive dynamic. This finding suggests that education policymakers should consider the synergistic interplay between external support and internal motivation when designing teacher development policies, rather than treating the two in isolation.

The Mediating Role of CBA Competence

The structural equation modeling results clearly demonstrate that CBA competence serves as a key mediating factor between TM and TDL. This finding indicates that the influence of motivation on digital literacy is not merely a direct translation of psychological energy into technical proficiency, but can also be realized and strengthened through the core component of classroom assessment within teaching practice.

Specifically, data analysis results support the transmission pathway "Motivation $\rightarrow$ CBA $\rightarrow$ DL". IM not only exerts a direct effect on TDL ($\beta = 0.271$), but also indirectly promotes its development by significantly enhancing teachers' CBA competence ($\beta = 0.173$). This finding enhances researchers' understanding of how motivation translates into teaching effectiveness. It suggests that teachers' acquisition and application of technology stem not only from training and personal interest, but also from engagement in practical problem-solving. Each dimension of assessment competence aligns with specific digital skill requirements in real teaching contexts—such as progress monitoring, needs analysis, instructional decision-making, and teaching evaluation. The completion of diverse teaching tasks is increasingly dependent on data-driven technological tools.

From the perspective of rural teacher development, this finding suggests that the enhancement of digital literacy should be closely integrated with specific teaching practices. The research model effectively integrates motivation theory (Ryan & Deci, 2000) with the "teaching practice" dimension emphasized in the Framework for Teacher Competency Development (Tondeur et al., 2023). Supporting teachers in applying digital tools to core instructional tasks—particularly classroom assessment—may more effectively stimulate their motivation to learn and facilitate the natural development of their professional competencies.

Therefore, the mediating relationship verified in this study suggests that advancing digital technology use among rural teachers should extend beyond merely providing technological tools or advocating for change. It is essential to focus directly on teachers' application of classroom assessment technologies, enhance their competence in conducting "teaching assessment" through targeted training, and ultimately facilitate a seamless transition from "knowing how to use" to "using effectively".

The Heterogeneous Impact of the CBA Competency Dimension

Educational assessment and progress monitoring as key drivers of digital literacy enhancement.

Educational assessment and progress monitoring demonstrate significant positive predictive effects on key dimensions of digital literacy, including professional development (PD), digital awareness (DA), digital application (DApp), Digital Technology Knowledge and Skills (DTKS), and digital social responsibility (DSR) ($\beta = 0.223-0.468$, $p < 0.01$; $\beta = 0.312-0.468$, $p < 0.01$). These results indicate that the greater a teacher's engagement in educational assessment and progress monitoring, the higher their level of digital literacy.

The quantitative analysis conducted in this study fills the previously untested pathway between CBA competence and TDL in the original model, thereby providing indirect support for the hypothesis that such competence exerts a positive facilitating effect on digital literacy development. This finding aligns with Li's (2022) research, which emphasizes that in educational assessment practices, teachers must actively employ digital tools to evaluate learning outcomes and adjust instructional strategies. Furthermore, F. L. Wu, F. F. Wu, and Luo (2019) highlighted that progress monitoring depends on teachers' data-driven decision-making capacity, manifested in their systematic understanding of instructional pacing and the learning process.

Indeed, both EdA and PoM require teachers to actively utilize digital tools—such as online assessment systems and learning analytics platforms—to collect, analyze, and apply instructional data. This process directly strengthens teachers' information technology proficiency and deepens their understanding of relevant technologies. It not only enhances digital application capabilities and technical knowledge, but also facilitates the transformation of digital literacy from cognitive comprehension to practical internalization. Therefore, the findings of this study provide empirical support for Huang and Zhang's (2024) theory of teachers' digital literacy development, particularly the "shaping stage", which posits that the core of this developmental phase lies in the integration of technology into authentic teaching practices, such as academic assessment and progress monitoring.

The inhibitory effect of IDM. IDM exerts a significant negative effect on all dimensions of digital literacy ($\beta = -0.473$ to -0.758), indicating a potential inhibitory pathway in the development of TDL. Early research by Mu (2015) emphasized that the richness of teachers' knowledge structure influences their decision-making capacity. Rural teachers often lack access to cutting-edge knowledge, educational theories, and developmental psychology, resulting in a narrow and experience-based foundation for instructional decisions. Wang (2020) further demonstrated that teachers exhibit insufficient understanding of digital technology integration within pedagogical content knowledge (PCK), leading to overreliance on experiential judgment and underutilization of the pedagogical value of digital tools. This study quantitatively confirms these findings. Effective IDM requires a high level of conscious awareness and a proactive attitude to transform traditional teaching paradigms. However, rural teachers frequently lack decision-making awareness, maintain teacher-centered instructional habits, and demonstrate limited initiative in exploring innovative practices. As a result, they tend to rely on habitual, experience-driven cognition, which constrains their capacity for autonomous and reflective decision-making.

(Zhang, 2022). Therefore, the deficiency in both awareness and competence among rural teachers constitutes a key factor underlying the inhibitory role of IDM in digital literacy advancement.

Existing research generally identifies the inadequacy of support systems as a key external factor constraining the development of TDL. Chen (2022) investigated that when teachers encounter operational difficulties in using new media terminal devices, not only is normal teaching progress disrupted, but students' learning flow may also be compromised due to improper technology use—undermining IDM effectiveness and confidence. Zhang (2022) indicated that in secondary school settings, insufficient multimedia hardware infrastructure and limited access to digital teaching resources constrain both the feasibility and scope for implementing instructional decisions. To a certain extent, high-quality IDM requires substantial support from multimedia equipment, laboratory instruments, and institutional teaching materials. The absence of such resources directly limits teachers' opportunities to experiment with and refine their teaching strategies within digitally enhanced classroom environments. This study further demonstrates that enhancing teachers' CBA competence fundamentally depends on strengthening internal motivation. High levels of internal motivation directly enhance teachers' ability to evaluate student responses, adjust instruction in real time, and accurately identify individual learning needs. External support—including adequate facilities, equipment, and positive interaction—exerts a direct influence on EM and assessment capability. However, the reinforcing effect of IM on CBA competence becomes significantly amplified only when external support—such as well-equipped classrooms and a conducive interactive environment—reaches a sufficient threshold.

Independence of IdSEN. The absence of a significant correlation between the identification of special educational needs and teachers' digital literacy is not confined to rural education in China, but reflects a broader challenge inherent in the global digital transformation of education systems. A 2022 report by the Organisation for Economic Co-operation and Development (OECD) revealed that, even in European Union countries with relatively advanced digital infrastructure, only 35% of teachers are proficient in using digital tools to effectively identify students' special learning needs. As observed in rural China, this gap largely arises from the current design of educational technology platforms, which tend to prioritize knowledge delivery over specialized diagnostic and assessment functionalities.

However, the challenges facing rural education in China are significantly more complex. In 2023, the Ministry of Education reported approximately 15.51 million left-behind children enrolled in compulsory education in rural areas. According to a 2021 survey conducted by Beijing Normal University, the academic performance of these children is on average 10-15% lower than that of their non-left-behind peers, and their dropout rate at the junior secondary level is 1.8 times higher. Data from the Institute of Psychology, Chinese Academy of Sciences, indicate that the prevalence of anxiety and depression among rural left-behind children exceeds 20%, with self-harm incidence rates among junior and senior secondary students reaching 5% to 8% in certain provinces. Zhang and Tao (2022) identified four key dimensions of special learning needs among left-behind students: educational, psychological, social and familial support, and technological and environmental support requirements. These needs are characterized by both complexity and multiplicity. Nevertheless, given the large scale of this population, IdSEN in rural settings depends predominantly on teachers' professional sensitivity and accumulated experiential expertise. A significant gap exists between available digital tools for identifying such needs and the educational platforms currently in use. While highly motivated and dedicated teachers in resource-limited contexts may detect evident anomalies and potential learning difficulties through

sustained observation and reflective practice, this capacity remains highly individualized and is largely unaffected by changes in external conditions. In the absence of adequate digital support systems, the relationship between IdSEN and TDL remains statistically insignificant.

Currently, the majority of digital platforms utilized in rural schools are primarily oriented toward knowledge delivery and administrative management, with limited integration of functionalities designed to identify or diagnose students' special educational needs. This functional misalignment poses a significant challenge for teachers seeking to apply their digital literacy skills in recognizing the diverse and complex academic and psychological needs of left-behind students. In particular, within rural schools facing constraints in digital infrastructure, technology remains largely supplementary to traditional teaching practices, rather than serving as an enabler of personalized, data-informed pathways for special education assessment. Although rural educators possess varying degrees of experience in using information technology, the lack of dedicated digital diagnostic frameworks means that their digital competencies cannot be effectively translated into timely and systematic identification of special educational needs.

Moreover, in the absence of effective technological support, the identification of students' special educational needs by rural teachers relies more heavily on professional sensitivity and long-accumulated teaching experience. As Zhang and Tao (2022) pointed out, rural teachers have developed a sensitivity-based judgment capacity regarding students' specific behavioral manifestations through observation, documentation, and reflective thinking. Li, Wang, and Yu (2022) further indicated that identifying and supporting the special needs of rural left-behind children is a complex undertaking. Relying solely on technological means to address their emotional and social needs is insufficient; the intrinsic value of teachers' human-centered judgment and intervention cannot be overlooked. Such identification, grounded in individual experience, exhibits characteristics of stability and context-dependency. Its effectiveness in recognizing students' special needs depends more on the teacher's intrinsic motivation and professional expertise than on external technological infrastructure. This aligns with the conclusion drawn in this study that internal motivation directly influences CBA, and also indirectly explains why the identification of special needs does not manifest a direct effect on the enhancement of digital literacy.

Conclusion

As the United Nations Sustainable Development Goal (SDG 4) identifies inclusive and equitable quality education as a core commitment, the development of TDL has become a focal point for educational researchers in both basic and higher education. However, the challenges associated with educational digital transformation in many developing countries and remote regions are commonly attributed to inadequate infrastructure and limited access to teacher training opportunities. This study, however, confirms that external environmental factors and formal training programs are not the sole pathways to enhance digital literacy among rural teachers.

This study, through the construction and validation of the "dual-path integration model of motivation and assessment competence", demonstrates that TM is a central driver in shaping the development of TDL, directly fostering rural teachers' proactive engagement in exploring and applying digital technologies within their instructional practice. At the same time, CBA competence cultivated by rural teachers in classroom settings functions as a pivotal mechanism linking technical knowledge with effective pedagogical behaviors, thereby enabling the meaningful and sustained integration of digital tools into teaching processes. The results further

reveal that motivation and assessment competence are not independent factors; instead, IM and CBA competence reciprocally reinforce one another, giving rise to a self-sustaining cycle of endogenous professional growth.

It is particularly noteworthy that the model reveals a structural conflict. IDM exerts a significant inhibitory effect on the improvement of TDL ($\beta = -0.473$ to -0.758). This finding indicates that, in the absence of sufficient support from subject matter knowledge, educational psychology, and technology-integrated pedagogical knowledge (such as technological pedagogical content knowledge, TPACK), rural teachers' instructional decisions tend to rely on traditional experience, which hinders the effective integration of digital tools into lesson design and classroom practice, thereby limiting the transformative potential of digital literacy in teaching.

Meanwhile, this study identifies a notable exception in rural education practice in China: IdSEN does not exhibit a significant correlation with their digital literacy levels. In the context of a large population of left-behind children with complex educational needs, the effectiveness of this ability depends more on teachers' professional sensitivity and individual experience than on general digital tools. This finding indicates that existing digital teaching platforms primarily focus on knowledge transmission and are generally lacking in functional features designed for professional diagnostic support and technology-enabled interventions.

Therefore, the fundamental pathway to sustainable development of digital literacy among rural teachers lies in transitioning from sole reliance on external resource inputs to cultivating endogenous developmental momentum. Moving forward, support for rural teachers' digital literacy should extend beyond basic technical training and embrace a dual-pronged mechanism that integrates motivational stimulation with assessment-based empowerment. The targeted design of reflective practice tasks, coupled with structured assessment support frameworks, can enhance rural teachers' professional agency and instructional decision-making capacity. This approach provides a practical action framework for addressing structural barriers to the digital transformation of rural education, thereby contributing to the achievement of the SDG 4 goal of quality education.

However, this study has certain limitations. China is a vast country characterized by uneven regional educational development and disparities in educational investment across regions. The current research focuses on rural teachers in western Guangdong Province. Although these teachers possess relatively extensive experience in digital teaching and reflect, to some extent, the typological characteristics of rural education, it remains unclear whether rural teachers in other regions are influenced by the same factors—particularly with regard to instructional decision-making and the ability to identify special educational needs. Therefore, future research should expand to broader geographical contexts to validate the applicability and effectiveness of the dual-path model of motivation and assessment ability across diverse rural education settings, as well as to conduct in-depth analyses of the specific contextual factors that influence the development of rural teachers' digital literacy.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

LW proposed the study protocol, analyzed the data, and wrote the paper. YH provided data validation and analysis tools. All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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