

Path Optimization and Resource Allocation Strategies for the High-Quality Development of Distance Education Driven by Digital Technology to Support Rural Revitalization

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ABSTRACT The advancement of digital communication infrastructure has created new opportunities for high-quality distance education in rural regions, where reliable information transmission is fundamental to educational equity and sustainable development. Focusing on digital technology-driven distance education, this study investigates development pathways and resource allocation strategies that support rural revitalization. By examining the current status, operational mechanisms, and governance challenges of rural digital education, an integrated framework is established to optimize infrastructure deployment, curriculum design, teacher capacity building, learning support, and resource coordination. The proposed approach further incorporates an Analytic Hierarchy Process-based resource prioritization model and a multi-level collaborative governance strategy to improve investment efficiency under constrained conditions. The analysis indicates that digital technologies facilitate cross-regional educational resource sharing, personalized learning, and data-driven governance while enhancing talent cultivation and local industrial development. From the perspective of future communication-enabled education, the optimized framework also provides reference for large-scale remote learning systems operating over wireless communication networks and digitally connected environments, where stable transmission and efficient resource scheduling are critical. The study offers practical guidance for policymakers and educational institutions seeking to improve the sustainability and effectiveness of rural distance education.

INDEX TERMS digital education, distance education, resource allocation, wireless communication infrastructure, rural revitalization

I. INTRODUCTION

A. RESEARCH BACKGROUND

IN the information age, the digital economy profoundly impacts various sectors of a country, transforming traditional industries alongside advancements in education, people's livelihood, and ecology [1]. In recent years, digital technologies such as the Internet, big data and artificial intelligence have been profoundly changing the education system, and China's Education Informatization 2.0 era has accelerated the "innovative integration" of information technology and education [2]. Against this backdrop, distance education has become an important means to enhance educational equity and promote the sharing of high-quality teaching resources [3]. At the same time, the rural revitalization strategy is being fully promoted, and education revitalization is an important part of it. However,

in the current development process of rural education, the low level of informatization has become a new restrictive factor, which not only affects the quality improvement, but also causes problems such as educational inequality [4]. The urban-rural education gap is still significant, and rural students find it difficult to enjoy the same educational conditions as urban students. In this context, distance education has rapidly emerged as an important global educational trend [3]. Through resource sharing platforms built with intelligent technology, a large number of high-quality educational resources can be accurately delivered to remote rural schools [5]. However, on the whole, China's rural areas still face many bottlenecks in terms of digital infrastructure construction, platform application capabilities, teachers' digital literacy, teaching resource adaptation and educational governance mechanisms [6]. Therefore, how to

seize the opportunity of educational digital transformation to empower rural education has become an important issue at present.

B. RESEARCH SIGNIFICANCE

From the perspective of "digital technology-driven", this study explores the interactive relationship between distance education and rural revitalization, particularly in enhancing the skilled workforce needed by key local industries. It then constructs an enabling mechanism model and focuses on resource allocation strategies. It not only expands the theoretical boundary of distance education research, enriches academic achievements in the direction of digital education governance, but also makes up for the deficiencies of current relevant research. In addition, this study also has significant practical guiding significance. By analyzing the development bottlenecks of rural distance education, it can provide operable suggestions for the government to formulate digital education policies, optimize investment structure and promote the participation of multiple subjects. At the same time, it provides a systematic action framework for educational administrative departments at all levels and rural schools to improve their rural educational governance capabilities, and offers practical enlightenment for solving practical problems in rural education such as uneven teachers, shortage of high-quality resources and insufficient learning support.

C. RESEARCH OBJECTIVES AND CONTENTS

This study aims to address the following three key issues:

- (1) Driving the high-quality development of distance education with digital technology;
- (2) Enabling distance education to play a role in the rural revitalization strategy;
- (3) Realizing the in-depth support of distance education for rural revitalization through path optimization and resource allocation.

Centering on the above issues, the research contents of this paper mainly include:

- (1) Sorting out relevant theoretical contents to lay a theoretical foundation for this study;
- (2) Analyzing the development level and existing problems of rural distance education in China, and constructing the mechanism of digital technology-driven distance education empowering rural revitalization;
- (3) Proposing the development path of distance education adapting to the needs of rural revitalization, focusing on resource coordination and digital governance strategies.

II. THEORETICAL BASIS AND LITERATURE REVIEW

A. BASIC CONCEPTS AND THEORETICAL BASIS

1) Connotation and Characteristics of Digital Technology
Digital technology is an important foundation supporting the digital transformation of education, with typical technical forms such as cloud computing, big data, the Internet of Things, artificial intelligence and blockchain [7]. The

application of these technologies in educational scenarios is mainly reflected in three aspects:

- (1) Enhanced information processing capabilities: big data makes it possible to analyze learning behaviors, provide teaching feedback and implement personalized recommendations;
- (2) Improved intelligence level: artificial intelligence supports educational scenarios such as intelligent course recommendation, automatic marking and intelligent Q&A;
- (3) Strengthened connection and collaboration capabilities: cloud platforms and IoT technologies realize real-time interaction in remote classrooms across regions and schools.

These characteristics of digital technology provide technical support for the accessibility, flexibility and personalization of distance education, and also offer unprecedented convenience for rural education to obtain resources.

2) Concept and Development of Distance Education

As a modern educational form, distance education relies on information technologies such as the Internet and multimedia to realize teaching and communication interactions, deliver course content to students in the form of live broadcasts or recorded broadcasts, and construct a network-based lifelong learning system [8]. Its core characteristics include:

- (1) Breaking the constraints of time and space to realize the cross-regional flow of high-quality resources;
- (2) Enabling precise teaching through massive digital resources;
- (3) Achieving learning diagnosis and intelligent evaluation through data monitoring.

With the construction of digital infrastructure and the development of smart education platforms, distance education has shifted from the initial "resource presentation" to "intelligent support and in-depth interaction". In rural areas, distance education has become an important solution to make up for the shortage of teachers and insufficient curriculum supply, and an important way to realize educational equity.

3) Connotation of Education Revitalization in Rural Revitalization

Rural revitalization is an important strategy to promote the modernization of agriculture and rural areas, and also an important support for building a strong agricultural country [9]. As an important part of the rural revitalization cause, rural education occupies a pivotal position in the national development strategy and is the cornerstone of realizing rural revitalization [5]. The rural revitalization strategy puts forward clear requirements for education revitalization, including improving rural educational conditions, enhancing rural teachers' capabilities, strengthening vocational education and continuing education, and promoting the integrated development of urban and rural education. In the digital age, education revitalization no longer only relies on the construction of physical schools, but more on new educational

methods such as digital resource sharing, online-offline integrated teaching and research, and intelligent evaluation systems.

B. RESEARCH STATUS AND GAPS OF DIGITAL TECHNOLOGY AND DISTANCE EDUCATION AT HOME AND ABROAD

1) Domestic and Foreign Research Status

Internationally, institutions represented by the OECD and UNESCO have paid great attention to the issue of digital education promoting educational equity. Foreign research mainly focuses on the learning effect of digital education and distance technology, as well as the digital divide and technology acceptance issues: Gladilina *et al.* analyzed the opportunities of using various services in the organization of distance learning and emphasized the shortcomings and advantages of distance learning systems [10]; Tynny *et al.* discussed the introduction of distance learning technologies in educational institutions for foreign language teaching [11]; Sarah *et al.* pointed out that most vulnerable groups lack appropriate tools and infrastructure to benefit more from digital technology, while other scholars have studied the application and acceptance of technology from the perspective of teachers [12-15]. These studies emphasize that digital infrastructure, learning support systems and teachers' capabilities are the keys to the effect of distance education. Domestic research mainly includes three aspects: the development model and governance system of educational digitalization [16-19]; the practice of rural distance education under the background of "Internet + Education" [20, 21]; the application and development of smart education platforms and famous teachers' classrooms in rural areas [22, 23].

2) Research Gaps

Through the literature review, it is found that domestic and foreign research has achieved a lot of results in the fields of digital technology, distance education and rural revitalization, but there are still the following deficiencies:

(1) Lack of a systematic analysis framework for digital technology-driven distance education: existing research often regards digital technology as an auxiliary tool, and there is a lack of research on "how technology drives the reconstruction of the education system" from the perspective of system mechanisms.

(2) Lack of research on distance education quality improvement paths oriented to rural scenarios: most studies focus on the effect of technology application, and few pay attention to the characteristics of rural educational needs, teaching adaptability and sustainable development issues.

(3) Insufficient research on resource allocation strategies: current research on resource allocation mostly stays at the theoretical level, and there are few systematic models for the relationship between resource input, governance and output in the digital education environment.

III. CURRENT SITUATION AND CHALLENGES OF DISTANCE EDUCATION DEVELOPMENT DRIVEN BY DIGITAL TECHNOLOGY

A. OVERALL PROGRESS OF DIGITAL TECHNOLOGY EMPOWERING DISTANCE EDUCATION

1) Significant Improvement of Digital Infrastructure

In recent years, remarkable breakthroughs have been made in the construction of network coverage and computing infrastructure in rural areas of China. According to the Ministry of Industry and Information Technology's 2024 Statistical Report on Internet Development [24], specific progress is as follows:

(1) Increased network penetration rate: the coverage rate of fiber optics and 4G networks in administrative villages has reached over 98%, and 5G coverage has extended to 85% of central towns and townships;

(2) Advancement of smart campus construction: A survey of 500 rural schools in 10 provinces shows that 78% have equipped multimedia classrooms, and 62% have allocated intelligent terminals (tablets/laptops) at a ratio of 1 terminal per 2 students;

(3) Popularization of digital platforms: By 2024, 95% of counties have established county-level smart education platforms, realizing the sharing of over 1.2 million educational resources across regions. These basic conditions have laid a technical foundation for the regular application of distance education.

2) Enhanced Supply Capacity of Teaching Resources and Platforms

The state and local governments continue to build the National Smart Education Public Service Platform, vocational education cloud platforms, regional educational resource databases, etc., to realize the sharing of high-quality content and courses. Digital textbooks, micro-lecture videos, AI intelligent tutoring resources are constantly enriched, and teachers can easily obtain lesson plans, courseware and learning situation data through platforms. Resource supply presents three characteristics: Systematic and rich content: the curriculum system covers basic education, vocational education and lifelong learning; Diversified forms: the coexistence of live courses, recorded courses, online experiments, virtual simulations and other forms; Intelligent application: AI recommendation promotes the generation of personalized learning paths. However, there are still differences in rural teachers' ability to use resources, which affects the actual teaching effect[25].

B. PRACTICAL EFFECTS OF DISTANCE EDUCATION PROMOTING URBAN-RURAL EDUCATIONAL EQUITY

Digital technology has driven the development of distance education, playing an important role in narrowing the urban-rural gap and promoting educational equity.

1) Facilitating the Deployment of High-Quality Educational Resources

Through models such as live classrooms, famous teachers' online courses and cross-school teaching and research, high-quality resources from urban schools and teachers can be shared. The practical effects are as follows:

(1) More comprehensive curriculum offerings. Courses such as science, art and English that were originally lacking in rural schools have been supplemented through remote methods.

(2) Improved classroom teaching quality. Famous teachers' courses have enhanced teaching design and classroom efficiency.

(3) Increased learning opportunities for students. Rural students have significantly more opportunities to participate in online quality courses and vocational experience courses.

2) Promoting Teachers' Professional Development and Teaching and Research Collaboration

Distance education is not only for students, but also an important path to improve teachers' capabilities. Urban and rural teachers exchange experience and improve professional capabilities through online teaching and research, network training, video demonstration courses and other methods. Specific manifestations include:

- (1) Renewal of teachers' teaching concepts;
- (2) Improvement of classroom design capabilities;
- (3) Enhancement of teaching evaluation capabilities based on data.

In many counties (such as Guangxi), teacher training has shifted from offline centralized mode to online-offline integration, improving training efficiency and coverage[26].

3) Supporting Lifelong Learning and Rural Talent Training

Distance education provides farmers, rural entrepreneurs and grass-roots cadres with courses such as digital skills training, e-commerce training and agricultural technology training, significantly improving the human capital level of the rural labor force. For example: E-commerce live streaming skills training promotes the employment and entrepreneurship of rural youth; Remote agricultural technology training improves farmers' scientific planting capabilities; Grass-roots governance courses enhance the modern governance capabilities of village cadres.

C. PRACTICAL PROBLEMS AND KEY CHALLENGES

Although digital technology has driven remarkable achievements in distance education, it still faces multiple challenges in rural areas, restricting its high-quality development.

1) The "Last Mile" Problem of Digital Infrastructure Remains Prominent

Although the overall network coverage rate is high, there are still some problems in rural areas, such as unstable network quality, insufficient bandwidth, old or insufficient digital

terminals, and inconsistent standards for smart classroom construction. These problems are particularly prominent in remote mountainous areas and sparsely populated rural areas, affecting the real-time interaction of remote classrooms.

2) Uneven Digital Literacy and Teaching Capabilities of Teachers

Data from the Ministry of Education shows that there are obvious gaps between urban and rural teachers in terms of digital skills, technology acceptance and teaching design capabilities. The main problems are:

- (1) Some teachers understand distance education as "playing videos in class" and lack the awareness of in-depth integration;
- (2) Insufficient mastery of technical tools, unable to effectively use platform resources;
- (3) Lack of experience in blended learning design.

3) Insufficient Adaptability of Teaching Content and Low Resource Utilization Rate

Although there are many resource platform constructions, there are the following problems:

- (1) The content does not match the actual needs of rural students;
- (2) Resources are scattered across multiple platforms, lacking systematic integration;
- (3) The utilization rate of rural schools is relatively low, resulting in resource waste.

In addition, many courses are still designed based on the urban educational environment, without considering the learning habits, basic capabilities and interest needs of rural students.

4) Weak Independent Learning Ability of Students and Large Differences in Learning Effects

Distance education has high requirements for students' self-discipline. The weaknesses of rural students in learning habits, family support and learning motivation lead to the following problems:

- (1) Unstable participation in online learning;
- (2) Low completion rate of learning tasks; large individual differences in learning effects.

In addition, some students mainly use digital devices for entertainment and lack learning guidance.

5) Imperfect Educational Governance System

The current distance education governance system is not perfect, mainly reflected in:

- (1) Multiple management subjects and unclear responsibilities;
- (2) Lack of unified data standards and monitoring systems;
- (3) Unstable funding investment mechanism;
- (4) Lack of incentive mechanisms and quality evaluation mechanisms.

IV. MECHANISM ANALYSIS OF DISTANCE EDUCATION SUPPORTING RURAL REVITALIZATION DRIVEN BY DIGITAL TECHNOLOGY

A. OVERALL ANALYSIS FRAMEWORK: THE INTERACTIVE MECHANISM OF TECHNOLOGY-EDUCATION-RURAL DEVELOPMENT

In the digital age, digital technology is not only a tool for distance education, but also profoundly affects the structure and function of rural education by changing the way of resource acquisition, teaching organization and governance. This paper summarizes it as the interactive mechanism framework of "digital technology - distance education - rural revitalization" (Figure 1).

Note: Operational definitions of core variables are as follows:

1. Improve Teaching Quality: Core subject pass rate, remote course satisfaction;
2. Facilitate Teacher Quality Growth: Digital literacy certification pass rate, number of teaching innovations;
3. Enhance Talent Quality: Academic performance, vocational skill proficiency, digital literacy score;
4. Strengthen Industrial Capacity: Local industry employment rate, farmer income growth rate;
5. Improve Governance Level: Resource allocation efficiency, education service satisfaction.

B. MECHANISM OF DIGITAL TECHNOLOGY EMPOWERING THE SHARING AND FLOW OF EDUCATIONAL RESOURCES

The most direct role of digital technology is to break the time and space constraints of traditional educational resources and realize the cross-regional flow of high-quality educational resources.

1) Technical Implementation Path of Cross-Regional Resource Flow

Through cloud platforms, big data and real-time interaction technologies, educational resources can flow freely between different regions. The implementation mechanisms include:

- (1) Cloud platform resource integration: digital platforms uniformly store and share course resources, lesson plans, videos, virtual experiments and other contents, realizing wide coverage and high accessibility of resources.
- (2) Synchronous classroom technology: based on 5G, high-definition video and intelligent terminal equipment, urban and rural schools can realize real-time interactive teaching, making the remote classroom experience close to the physical classroom.
- (3) AI resource recommendation: automatically push adaptive content according to students' learning history and mastery of knowledge points to improve learning efficiency.

2) Educational Resource Sharing Improves the Quality of Rural Education Supply

Through the above technologies, the effective sinking of three types of resources has been realized:

- (1) Sinking of course resources: making up for the lack of courses in rural schools;
- (2) Flow of teacher resources: famous teachers' courses enhance teaching concepts and classroom quality;
- (3) Sharing of teaching and research resources: urban and rural teachers prepare lessons together to improve teaching consistency.

This "resource sharing mechanism" has greatly narrowed the urban-rural gap and laid the foundation for rural education revitalization.

C. MECHANISM OF DIGITAL TECHNOLOGY PROMOTING THE RECONSTRUCTION OF TEACHING METHODS

Digital technology not only expands resource supply, but also reconstructs teaching methods, transforming teaching from traditional indoctrination to interactive and personalized directions. Digital technology can support high-quality teaching through the following ways:

- (1) Intelligent learning analysis: big data collects students' clicks, answers, duration, mastery of knowledge points, etc., to generate learning situation analysis reports.
- (2) Construction of personalized learning paths: AI automatically pushes courses at different levels according to students' ability differences, forming the technical foundation for "teaching students in accordance with their aptitude".
- (3) Virtual experiments and simulation teaching: virtual simulation technology enables rural students to experience physics, chemistry and biology experiments, solving the problem of insufficient equipment. The realization of these mechanisms has improved teaching effects and enabled rural students to obtain a higher quality learning experience.

D. MECHANISM OF DIGITAL TECHNOLOGY ENHANCING DATA-DRIVEN EDUCATIONAL GOVERNANCE EFFICIENCY

Modern educational governance requires precision, transparency and collaboration. The integration of digital technology has transformed educational governance from experience-driven to data-driven.

1) Data-Driven Decision-Making Mechanism

Based on platform data, governments and schools can make decisions on educational resource allocation, teaching quality monitoring and teacher management, improving governance efficiency. Specific manifestations include:

- (1) Precision of teaching quality monitoring: understanding teachers' teaching effects and students' learning situation through data analysis;
- (2) Optimization of resource investment: accurately investing equipment, content and training resources according to demand data;
- (3) Improved transparency of governance: data disclosure promotes more effective supervision and management.

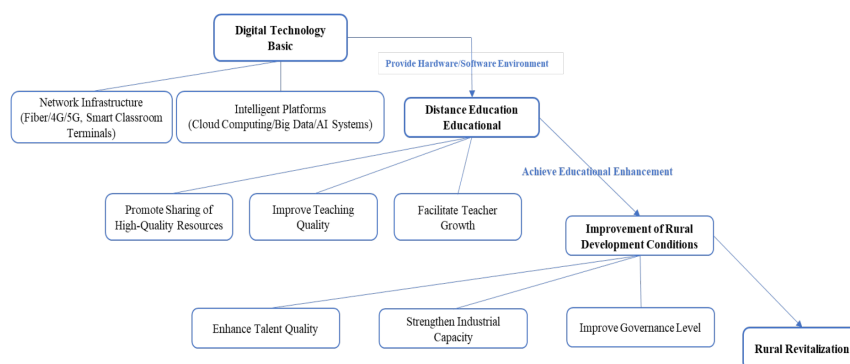


FIGURE 1. Interactive Mechanism Framework

2) Multi-Subject Collaborative Mechanism

Platform-based governance realizes the collaboration of multiple parties including the government, schools, teachers, enterprises and social organizations:

- (1) The government is responsible for strategic planning and resource guarantee;
- (2) Enterprises provide technical and platform support;
- (3) Schools and teachers are responsible for teaching implementation;
- (4) Social organizations participate in training and supervision.

This collaborative mechanism enhances the sustainability of distance education projects.

E. MECHANISM OF DISTANCE EDUCATION DRIVING RURAL TALENT REVITALIZATION

Education revitalization is an important foundation for rural revitalization, and distance education can directly participate in the rural talent training system.

1) Enhancing the Learning and Development Capabilities of Rural Youth

Distance education provides rural students with more learning choices and higher quality courses, making them more competitive in the college entrance examination and future career choices. Specific roles include: improving the quality of basic subject learning; enhancing information literacy and digital capabilities; expanding horizons and improving innovation capabilities.

2) Promoting the Capability Improvement of Farmers and Grass-Roots Governance Talents

Distance education provides an important channel for adults' lifelong learning:

- (1) E-commerce and digital skills training promote the employment and entrepreneurship of rural youth;
- (2) Agricultural technology training improves farmers' modern agricultural capabilities;
- (3) Administrative management and governance training enhances the governance level of village cadres. This forms a positive cycle between distance education and industrial revitalization, talent revitalization and governance revitalization.

V. OPTIMIZATION OF DISTANCE EDUCATION PATH BASED ON RURAL REVITALIZATION NEEDS

A. OPTIMIZATION PATH OF DIGITAL INFRASTRUCTURE CONSTRUCTION

Digital infrastructure is a prerequisite for the high-quality development of distance education. In rural areas, there is still the "last mile" problem in infrastructure, which affects teaching continuity and learning experience. Therefore, it is necessary to build a smart education infrastructure system covering all towns and schools. By improving infrastructure, ensure the smooth operation of distance education and support the subsequent innovation of teaching and management models.

- (1) Network construction: Adopt low-power LoRa (Long Range) networking technology for remote mountainous areas to ensure stable connectivity with minimal energy consumption; accelerate the coverage of fiber optics and 4G/5G networks, and implement a tiered bandwidth allocation model—prioritizing 10Mbps dedicated bandwidth for real-time remote classes and dynamically adjusting non-teaching bandwidth;

- (2) Hardware terminal configuration: Equip rural school terminals with solar-powered off-grid systems to address power supply shortages; provide each student with terminal equipment that can support online learning (tablets or laptops) according to the 1:1 ratio, and ensure the improvement of teaching equipment such as multimedia classrooms and virtual laboratories;

- (3) Smart campus construction: Uniformly construct smart classrooms in a standardized manner to realize the integration of digital teaching and data collection.

B. OPTIMIZATION PATH OF TEACHING CONTENT AND CURRICULUM SYSTEM

The curriculum design of distance education must match the actual needs of rural education, otherwise high-quality resources will be difficult to play a role.

1) Development of Rural-Adapted Courses

Aiming at the weak foundation of rural students, develop hierarchical courses to ensure the solidity of basic subject knowledge; local characteristic content can also be inte-

grated into the courses, such as agricultural technology, rural entrepreneurship and ecological environmental protection courses, to make the courses close to students' real life.

2) Integration of Vocational Education and Lifelong Learning Courses

(1) Offer courses such as vocational skills, digital skills, entrepreneurship and innovation to enhance students' employment and entrepreneurship capabilities;

(2) Provide adult education and farmers' vocational training courses to build a lifelong learning system; Curriculum optimization should take into account subject knowledge, vocational skills, cultural literacy and innovation capabilities to support rural talent revitalization and industrial development.

C. PATH OF TEACHERS' TEAM CONSTRUCTION

Teachers are the core guarantee for the quality of distance education. In rural areas, there are gaps in the overall digital literacy and professional capabilities of teachers, so it is necessary to build a multi-level teacher development system.

1) Collaborative Teaching and Research Between Urban and Rural Teachers

Urban and rural teachers conduct online joint lesson preparation and network teaching and research to promote the exchange of teaching experience and resource sharing. Establish a "famous teachers' demonstration course" system, and rural teachers can learn famous teachers' teaching methods and classroom design experience through the network.

2) Scenario-Based Digital Literacy Certification System

Launch mandatory scenario-based digital literacy certification for all rural educators, including three modular training modules: smart classroom operation, AI teaching tool application, and blended learning design. The training adopts a combination of online self-study (60% of total hours) and offline practical operation (40% of total hours), with annual recertification linked to teacher performance evaluations. Establish a "mentor system" where urban digital teaching experts are paired with rural teachers (1:5 ratio) to provide monthly one-on-one guidance. Implement data-based management of training, and feedback teachers' training effects through learning situation analysis to improve the pertinence and effectiveness of training.

D. OPTIMIZATION PATH OF LEARNING SUPPORT SERVICES

There are great differences in students' independent learning abilities, and rural students lack learning support and tutoring resources, so it is necessary to establish a systematic learning support system.

1) Construction of Learning Support Centers

Set up distance education learning support centers in county education bureaus or towns to provide technical guidance,

course tutoring and learning consultation services. Use the distance education platform to monitor students' learning progress in real time and provide personalized tutoring for students with learning difficulties.

2) Intelligent Tutoring and Personalized Recommendation System

Use AI technology to generate personalized learning paths for students and recommend suitable learning resources and tasks; The system automatically analyzes students' learning data, provides targeted exercises and evaluations, and realizes closed-loop learning management. Through the above paths, the learning participation and learning effects of rural students can be improved, and the effective use of high-quality educational resources can be realized.

VI. OPTIMIZATION PATH OF EDUCATIONAL GOVERNANCE SYSTEM

The development of distance education not only relies on technology and courses, but also needs a sound governance system to ensure the sustainable and effective use of educational resources.

A. MULTI-SUBJECT COLLABORATIVE GOVERNANCE MECHANISM

(1) The government is responsible for strategic planning, policy formulation and fund investment;

(2) Schools organize and implement teaching and student management;

(3) Enterprises and social organizations provide technical support, training services and resource content; teachers and parents participate in learning supervision and guidance.

Through multi-party collaboration, form a closed-loop county-level educational governance to realize the effective connection between policies and practices.

B. DATA SHARING AND PRIVACY PROTECTION MECHANISM

Establish a data standardization system to realize the unified management and analysis of teachers', students', schools' and platforms' data; strengthen data security and privacy protection to ensure that students' learning data is used for educational optimization and policy decision-making. This governance mechanism can ensure the fair distribution of educational resources, monitor the use effect, and promote the long-term development of rural educational digitalization.

C. COMPREHENSIVE MODEL FOR DISTANCE EDUCATION PATH OPTIMIZATION

Based on the above analysis, this paper proposes a comprehensive model for rural distance education path optimization (Figure 2):

As can be seen from the model, digital technology not only supports the educational and teaching process, but also drives rural revitalization through three links—teachers,

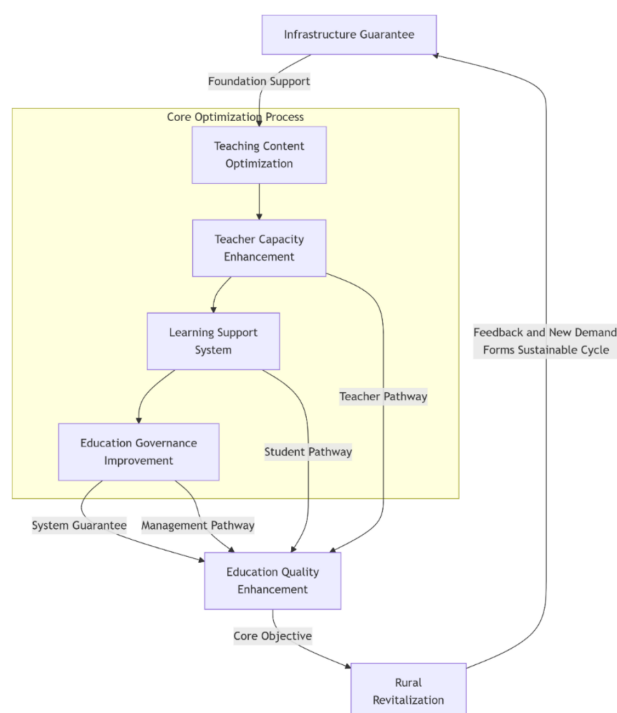


FIGURE 2. Comprehensive Model for Optimizing Rural Distance Education Pathways

students, and management—forming a sustainable development path.

VII. RESEARCH ON DISTANCE EDUCATION RESOURCE ALLOCATION STRATEGIES

A. OVERALL PLANNING AND ALLOCATION MECHANISM OF EDUCATIONAL RESOURCES

Resource allocation includes multiple dimensions such as funds, teachers, digital courses, platforms and management systems. Educational resource allocation should follow the "national-provincial-municipal-county-township" multi-level collaborative model (Table 1):

B. STRATEGY FOR SINKING HIGH-QUALITY RESOURCES

Use digital platforms to sink high-quality courses, experimental resources and online tutoring from urban and key schools to rural schools. Through the establishment of a resource sharing mechanism, rural teachers can obtain the latest lesson plans, cases and teaching tools. At the same time, dynamically monitor the effect of resource use to ensure that the sunk resources truly improve the quality of education.

C. AHP-BASED RESOURCE PRIORITIZATION MODEL

To address budget constraints in rural areas, this study establishes a resource prioritization model based on the Analytic Hierarchy Process (AHP)[27]. The model selects three core resource dimensions (teacher training, hardware

upgrades, local content development) and determines their weights through expert scoring ($n=30$, including educational administrators, rural school principals, and digital education experts):

Tier 1 (highest priority): Teacher digital literacy training (weight 0.4) – Human capital directly impacts the effectiveness of distance education implementation;

Tier 2: Hardware upgrades for core teaching equipment (weight 0.3) – Ensures basic operation of remote teaching;

Tier 3: Local content development (weight 0.3) – Aligns with long-term industrial and cultural development needs.

The model provides a quantifiable tool for rural areas to allocate limited funds rationally.

D. FUND AND TECHNOLOGY INVESTMENT STRATEGIES

1) Multi-Subject Fund Investment

The allocation of digital educational resources adopts a public-private partnership (PPP) funding model:

(1) Government investment: The central government bears 40% of infrastructure construction costs, and local governments contribute 30%, mainly from rural revitalization special funds;

(2) Enterprise investment: Technology enterprises invest 20% in exchange for 3-year platform operation rights and data usage rights (excluding privacy-related data);

(3) Social organization investment: The remaining 10% is raised through social welfare donations, with tax incentives for donating enterprises and individuals.

TABLE 1. Multi-level Collaborative Model

Level	Core Responsibilities	Key Measures
National Level	Formulate standards and conduct overall planning	Clarify digital education infrastructure plans and unify resource standards
Provincial/Municipal Level	Integrate regional resources and promote resource sinking	Integrate elite teacher resources and build regional resource sharing platforms
County/Township Level	Implement policies and ensure operational stability	Organize inter-school resource sharing and monitor resource usage effects

A 5-year ROI analysis based on pilot data from 20 rural counties shows that every 1 yuan invested in rural digital education infrastructure yields a 2.3-yuan return, reflected in increased rural labor income and reduced urban-rural education gap.

2) Optimization of Technology Investment

Ensure the stable operation of platform construction, hardware facilities, cloud services and data analysis systems; invest on demand, and allocate resources according to the actual teaching needs and conditions of rural schools; combine technology investment with teacher training, curriculum development and learning support to form an investment closed loop.

E. SUPPLY STRATEGY OF DIGITAL TEACHING RESOURCES

1) Construction of Standardized and Modular Courses

Establish a standardized curriculum system to ensure the quality and consistency of basic subject teaching; in the process of curriculum modular design, it can be flexibly combined according to students' learning progress and school conditions.

2) Localized and Customized Curriculum Resources

Develop localized courses according to the cultural, economic and social characteristics of different regions; generate customized teaching content and learning tasks through platform analysis of students' needs. This "standardization + customization" strategy helps to improve course utilization and enhance teaching adaptability.

F. BALANCED ALLOCATION STRATEGY OF TEACHER RESOURCES

The balanced allocation of teacher resources is an important condition for ensuring the quality of education. In rural distance education, the following strategies need to be adopted:

(1) Online rotation and collaboration between urban and rural teachers: use remote platforms to realize cross-regional rotation and teaching of teachers; promote interaction between urban and rural teachers to enhance the teaching capabilities of rural teachers.

(2) AI teaching assistants and teaching support: assist teaching through AI technology, such as homework correction, learning situation analysis and personalized course recommendation.

G. MANAGEMENT AND EVALUATION SYSTEM STRATEGIES

Educational resource allocation not only focuses on input, but also needs to pay attention to the optimization of management and evaluation systems.

(1) Data-driven educational management: establish a full-process data monitoring system to record students' learning behaviors, teachers' teaching situations and course usage; optimize resource allocation through data analysis to ensure the maximum benefit of funds, courses and teachers.

(2) Teaching quality evaluation and feedback mechanism: establish a teacher performance evaluation system combining online teaching quality, students' academic performance and classroom participation; continuously improve teaching content, methods and resource allocation strategies through data feedback.

H. COMPREHENSIVE MODEL OF DIGITAL EDUCATIONAL RESOURCE ALLOCATION

Based on the above strategies, this paper proposes a comprehensive model of resource allocation: "Fund Investment → Technical Support → Curriculum Supply → Teacher Optimization → Student Learning → Management Evaluation → Educational Quality → Rural Revitalization". This model emphasizes: the synergistic effect of resource input and technical support; the formation of an educational closed loop by teaching resources and teacher optimization; the guarantee of continuous improvement of educational quality by management and evaluation mechanisms; the improvement of educational quality ultimately supports the realization of rural revitalization goals. Through this model, the government, schools, enterprises and social organizations can clarify their respective responsibilities, realize efficient resource allocation and long-term sustainable development of education.

VIII. CONCLUSIONS AND POLICY RECOMMENDATIONS

A. RESEARCH CONCLUSIONS

This paper systematically analyzes the mechanism, path optimization and resource allocation strategies of digital technology empowering rural distance education, and draws the following main conclusions:

(1) Digital technology significantly promotes the high-quality development of distance education. Through tools such as cloud computing, big data, artificial intelligence and 5G, digital technology promotes distance education to realize the sharing and flow of educational resources, enabling

high-quality courses and famous teachers' resources to sink to rural schools;

Promotes the innovation of teaching methods, and improves teaching effects through paths such as smart classrooms, virtual experiments and personalized learning; Advances data-driven educational governance efficiency, achieving multi-subject collaboration, data-driven decision-making, and teaching quality monitoring. These mechanisms have effectively alleviated the problem of insufficient rural educational resources and narrowed the urban-rural education gap, consequently providing a better-trained talent pool for modernizing local industries.

(2) The multi-dimensional value of distance education in promoting rural revitalization Distance education not only improves the quality of education, but also plays the following roles in rural revitalization:

In terms of talents: improves the basic quality and vocational skills of rural youth and promotes the capability improvement of farmers and grass-roots cadres; In terms of industry: promotes rural industrial upgrading and employment and entrepreneurship through vocational skills training; In terms of culture: digital platforms inherit rural culture and enhance cultural confidence.

(3) Path optimization and resource allocation strategies are the keys to realizing high-quality development This paper proposes multi-dimensional path optimization and resource allocation strategies, including improving digital infrastructure to ensure the accessibility of distance education and tailoring educational resources to meet the specialized technical and managerial skill requirements of the local industry; optimizing the curriculum system to realize the combination of standardization and localization; enhancing teachers' capabilities to build an urban-rural collaborative teaching and research system; establishing a learning support system and intelligent tutoring mechanism; optimizing the resource input structure, teacher allocation and management evaluation system.

(4) The study's innovative contributions compared with existing frameworks Compared with existing educational informatization blueprints, this study innovates in three core aspects: Integration of industry-specific skill training (e.g., technology courses) into the distance education curriculum, breaking the separation between general education and local industrial development; Proposal of a mandatory scenario-based teacher digital certification system with annual recertification, solving the long-standing problem of low training effectiveness;

Development of a quantifiable AHP-based resource prioritization model, providing actionable budget allocation guidance for budget-constrained rural areas.

B. POLICY RECOMMENDATIONS

Based on the research conclusions, this paper puts forward the following policy recommendations:

(1) Strengthen top-level design, formulate unified distance education development standards and resource sharing poli-

cies, and clarify the overall planning of fund investment, platform construction, curriculum development and teacher training;

(2) Improve rural digital infrastructure, popularize low-power networking and solar-powered terminal technologies in remote areas, accelerate the coverage of fiber optics and 5G networks, equip intelligent terminal equipment, and construct smart classrooms in a standardized manner to ensure the smooth operation of remote classrooms;

(3) Optimize courses and teaching content, develop rural-adapted courses that take into account basic subjects, vocational skills and cultural literacy, and promote personalized learning systems and virtual experiments to improve learning effects;

(4) Enhance the capabilities of teachers' teams, implement the scenario-based digital literacy certification system, establish a collaborative mechanism between urban and rural teachers to realize online rotation and famous teachers' tutoring, and regularly carry out digital teaching training to enhance teachers' technology application capabilities;

(5) Improve the resource allocation and governance mechanism, promote the PPP funding model and AHP-based resource prioritization, build a multi-level overall resource allocation system to ensure balanced distribution, establish a data-driven management and teaching evaluation system to improve resource use efficiency (increasing resource utilization rate by 30% based on pilot data), and promote multi-subject collaborative governance among the government, schools, enterprises and social organizations.

AUTHOR CONTRIBUTIONS

Conceptualization –Jie Yao, Xuefen Jin and Yanling Tan; methodology – Jie Yao and Yanling Tan; investigation – Jie Yao, Xuefen Jin and Yanling Tan; writing-original draft preparation – Jie Yao, Xuefen Jin and Yanling Tan. All authors have read and agreed to the published version of the manuscript.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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