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The Study on the Equitable Allocation Mechanism of High-Quality Digital Resources in Compulsory Education in Sichuan Ethnic Regions

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Abstract:
The optimal allocation of digital educational resources, as the key to effectively leveraging high-quality digital educational resources, represents one of the core issues urgently requiring resolution in both the practical and theoretical research on digitization of compulsory education in ethnic minority areas of Sichuan. This study draws upon perspectives such as coordinated resource allocation, equalization of public services, market-based allocation, and performance improvement, while incorporating system dynamics methods and performance technology. It conducts field investigations in primary and secondary schools across W County, X City, and K City in the ethnic regions of Sichuan. Subsequently, by establishing a dynamic model of the digital resource allocation mechanism for compulsory education, the research explores the formation mechanisms underlying the unequal distribution of high-quality digital educational resources in these areas. Finally, based on policy simulation, it proposes concrete pathways tailored to achieve equitable development of high-quality digital resources for compulsory education in the region.

Keywords:
Sichuan Ethnic Regions; *Compulsory education*; *Equalization of digital resource allocation*; *Policy simulation*

1. Introduction

In January 2025, the issued *Outline of the Plan for Building a Strong Education Nation (2024–2035)* explicitly called for "implementing the national education digitalization strategy" and "developing new types of digital educational resources" [1]. While compulsory education digitization in the ethnic regions of Sichuan has entered a phase of rapid development, issues such as imbalanced regional progress in educational digitization and imperfect mechanisms for the supply and demand of digital educational resources have become increasingly prominent, hindering the high-quality development of compulsory education in these areas. A review of the literature and field investigations reveal that the optimal allocation of digital educational resourc-

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es, crucial for the effective utilization of high-quality digital resources, stands as one of the core problems urgently needing resolution in both the practice and theoretical research of compulsory education digitization in Sichuan's ethnic regions. This study, grounded in perspectives including coordinated resource allocation, equalization of public services, market-based allocation, and performance improvement, and incorporating system dynamics methods and performance technology, aims to establish a dynamic model of the digital resource allocation mechanism for compulsory education. It seeks to explore the formation and operational mechanisms behind the unequal distribution of high-quality digital educational resources in this region. Finally, based on policy simulation, the study will propose concrete pathways suited for achieving equitable development of high-quality digital resources in compulsory education within the area.

2. Literature Review

2.1 Research on the Development History of Education Digitalization

In 1996, the United States took the lead in proposing a development plan for education digitalization. In 2010, it released the National Education Technology Plan, aiming to "transform American education: leveraging technology to enhance learning." In 2011, its Strategy for American Innovation further introduced the "Online Learning Transformation Plan" to achieve a leap in educational technology, thereby consolidating and maintaining the U.S. leading edge in education globally. In 2010, Japan issued the Guidelines for Education Digitalization, promoting the application of information technology across nine areas, including learning, usage, and enhancing teachers' instructional capabilities. In 2011, South Korea launched the "Smart Education Strategy," investing 2 billion USD to develop digital textbooks, implement teacher retraining programs, and establish online cloud platforms, announcing that all paper textbooks in schools would be replaced by digital ones by 2015. In 2012, the United Kingdom added 160 million pounds to its science and education budget for information infrastructure construction, aiming to facilitate easier sharing of vast research data among schools.

Simultaneously, China, in its *National Medium- and Long-Term Education Reform and Development Plan Outline (2010–2020)* promulgated in July 2010, stated that "information technology has a revolutionary impact on educational development and must be accorded high importance," dedicating a separate chapter to elaborate on "accelerating the process of education digitalization." In March 2012, the released *Ten-Year Development Plan for Education Digitalization (2011–2020)* explicitly outlined the working principles for education digitalization: to explore the comprehensive and deep integration of modern information technology with education, to lead innovation in educational concepts and models through digitalization, and to fully leverage the supportive and leading role of education digitalization in educational reform and development. In February 2019, Part Eight, "Accelerating Educational Transformation in the Information Age," of the published China's Education Modernization 2035 focused on building smart campuses, utilizing modern technologies to accelerate reforms in talent cultivation models, innovating education service formats, and promoting changes in educational governance approaches. In January 2025, the issued *Outline of the Plan for Building a Strong Education Nation (2024–2035)* explicitly called for "implementing the national education digitalization strategy" and "developing new types of digital educational resources." In February 2025, the General Office of the Ministry of Education issued the Administrative Measures for Education Digitalization Standard-

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ization Work, clarifying that education digitalization standards cover seven major categories of recommended standards — facilities and equipment, software and data, cybersecurity, digital resources, digital literacy of teachers and students, etc.—and a dynamic management mechanism for standards.

The series of documents promulgated by China, the United States, Japan, South Korea, and others all emphasize promoting the development and widespread application of digital educational resources, facilitating the sharing of high-quality digital educational resources, and driving education modernization through education digitalization. How to implement the allocation and sharing of high-quality digital educational resources is one of the core issues urgently needing resolution in advancing the process of education digitalization.

2.2 Research on the Development History of Equalizing Digital Educational Resources

This development primarily consists of the following three stages: **(1) Germination Stage (1960s–1990s):** This stage is represented by the establishment of four network nodes in the late 1960s under the ARPANET project at institutions such as the University of California, Los Angeles, for experimental data transmission and document sharing [2]. In China, the emergence of digital educational resources was marked by the initial preparation of the "Central Resource Repository" in 1997. During this period, public educational resource services began to permeate the education field through computer technology, gradually forming digital educational resources. Through the development in this germination stage, China formed a rudimentary model for the equalization of public services for digital educational resources characterized by "regional support and grassroots selection" [3].**(2) System Building and Model Exploration Stage (Late 1990s – Early 21st Century):** In the early phase of this stage, factors such as improved network transmission speeds due to fiber-optic networks, technological iterations from Web 2.0 to Web X, and the normalization of mobile internet usage supported various learning forms including fragmented, ubiquitous, socialized, and personalized learning. Multiple stakeholders including governments, academia, enterprises, and society participated, promoting the continuous improvement of China's digital educational resources as a component of the public service system [4]. Concurrently, countries worldwide and international organizations gradually recognized the strategic significance of incorporating digital educational resources into public service systems for educational development. They began focusing on research regarding Open Educational Resources (OER) in areas such as promoting educational equity [5], narrowing international and regional educational disparities, and facilitating cross-cultural communication [6]. **(3) Digital and Intelligent Transformation Stage (Early 21st Century – Present):** With the rapid advancement of digital and intelligent technologies, artificial intelligence, blockchain, and big data are quickly permeating the education sector. Initiatives such as the EU's 2030 Digital Compass: the European way for the Digital Decade, Japan's "Society 5.0", and South Korea's "Digital New Deal" are actively committed to the digital and intelligent development of educational resources [7]. China has consistently attached great importance to education digitalization. Documents such as *the Outline of the Plan for Building a Strong Education Nation (2024–2035)* and *the Opinions of the Ministry of Education and Eight Other Departments on Accelerating the Advancement of Education Digitalization*, promulgated in January 2025, call for "prioritized support for rural areas, ethnic regions, and areas that have recently emerged from poverty." The focus is on developing resource access, platform customization, teaching methods, and evaluation towards a direction of co-construction and sharing [8]. Currently, digital educational resources worldwide are progressively being incorporated into the realm of public services and are developing towards

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co-construction, sharing, and digital-intelligent transformation.

2.3 Research on the Development of Digital Educational Resources

This primarily focuses on the following five aspects. First, regarding environmental platforms, the main concerns involve platform construction, security assurance, standard conversion, and copyright protection for digital educational resources [9]. Second, in terms of resource creation, the focus lies on the development of teaching resources, the establishment of resource repositories, course resource development, and resource creation technologies. Third, concerning resource co-construction and sharing, key topics include the strategic significance of implementing a "public construction, mass sharing" model for digital learning resources [10], the establishment of the "categorized information sharing" concept, ecological perspective analysis, overarching goals for co-construction, mechanisms for co-construction and sharing, development and application models for "regional co-construction and sharing," conceptual models for sustainable development mechanisms, and precision delivery, among others. Fourth, regarding resource utilization, research covers the design of interoperability technologies, strategies for promoting the integration of online educational resources, and the integration of resources within modern distance education projects. Fifth, in the area of resource evaluation, current approaches within computing research are primarily determined by the evolution of methods for assessing the usability of digital educational resources. In educational research, evaluation standards for digital educational resources mainly focus on aspects such as educational games, digital textbook development, applied games, mobile educational games, online learning, learning support platforms [11], children's mobile applications, usability within Moodle, mobile learning applications, and online learning platforms [12].

2.4 Research on the Sharing of Digital Educational Resources

This encompasses the following four areas of study. First, research on resource sharing based on knowledge graphs. Currently, numerous large-scale knowledge bases and graphs exist worldwide, such as Google Knowledge Graph, DBpedia, Wikidata, Freebase, Wolfram Alpha, CN-DBpedia, and Sogou's "Zhilifang." In terms of type, they include internationally general comprehensive subject-based graphs, domain-specific graphs, and cross-lingual graphs.

Second, research on resource sharing based on concept maps. As "concept maps" are widely applied in the efficient teaching and classroom quality performance evaluation processes in primary, secondary, and university classrooms, they have become effective aids in constructing efficient teaching environments. However, issues remain, such as the immaturity of ontology concepts, their theories and technologies, and insufficiently deep application in the educational domain. Currently, personalized application-oriented learning models based on semantic networks have emerged as a new breakthrough direction in academia.

Third, research on dynamic semantics of educational resources. Some scholars argue that data aggregation based on RSS, data aggregation based on RSS Web services, and digital resource aggregation based on databases and semantics each have their own characteristics and applications [13].

Fourth, analysis of knowledge base technologies. While providing each student with comprehensive information resources and technical support, knowledge bases also face challenges related to the representation and presentation of knowledge, their own architecture and management, and the collection and acquisition of

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knowledge [14].

2.5 Analysis of Issues and Causes Regarding Unequal Allocation of Digital Resources in Compulsory Education in China's Ethnic Regions

This includes research in the following four areas. First, low efficiency in construction funding investment. The causes include a mismatch between the cost characteristics of educational resource allocation and the awareness of some educational management staff, the influence of narrow egalitarianism hindering the achievement of economies of scale, and irregularities in investment structure, efficiency evaluation processes, and supervision. Second, a scarcity of high-quality digital educational resources. The causes lie in the tendencies to "prioritize infrastructure over personnel," "focus on hardware over software," and "emphasize quantity over quality." Third, low utilization rates of digital educational resources. Contributing factors include "emphasizing construction over application" and "prioritizing teaching over learning" [15]. Fourth, imbalanced allocation of digital educational resources. Causes encompass closed-off and isolated mindsets, a unidirectional linear approach, neglect of equal opportunity, and the lack of a unified development model, among others [16]. Among these, the concurrent issues of insufficient funding investment and low efficiency are considered by academia to be particularly prominent problems.

2.6 Literature Review

As evident from the above literature, scholars have discussed various aspects, including the development history of education digitalization, the evolution of equalizing digital educational resources, resource development, resource sharing, and issues and causes related to the allocation of digital resources in compulsory education in ethnic regions. They recognize that network technology serves as a crucial pathway for optimizing the allocation of digital educational resources, and numerous practical experiences have been summarized. However, certain issues—such as the entrenched mindset in primary and secondary schools of "averagely" distributing digital resources based solely on student numbers, and the performance shortcomings of using evaluation indicators to guide digital resource allocation—have negatively impacted the allocation and utilization efficiency of high-quality digital educational resources, yet these have not been thoroughly explored. Meanwhile, primary and secondary schools in ethnic regions continue to face prominent problems, including insufficient funding for digital educational resources, low efficiency, and inadequate allocation of high-quality resources, all of which hinder the level of informatization development in schools within educationally disadvantaged areas of Sichuan's ethnic regions.

This study strives to move beyond the narrow notion that "educational resources must be built solely by the education system." It attempts to use resource utilization rates as a basis for evaluating allocation performance, implements differential allocation following market competition principles, and emphasizes improving performance through internal structural adjustments and external incentives within the system. From the perspectives of enhancing resource quality and increasing utilization rates, it aims to construct a measurement model for procuring high-quality digital educational resources and a strategic model to incentivize users. By integrating economic and technical means to regulate the allocation of digital educational resources, it seeks to establish a new collaborative allocation model characterized by "co-construction and sharing within regions, and exchange and sharing between regions."

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3. Methods and Procedures

3.1 Research Methods and Technical Approach

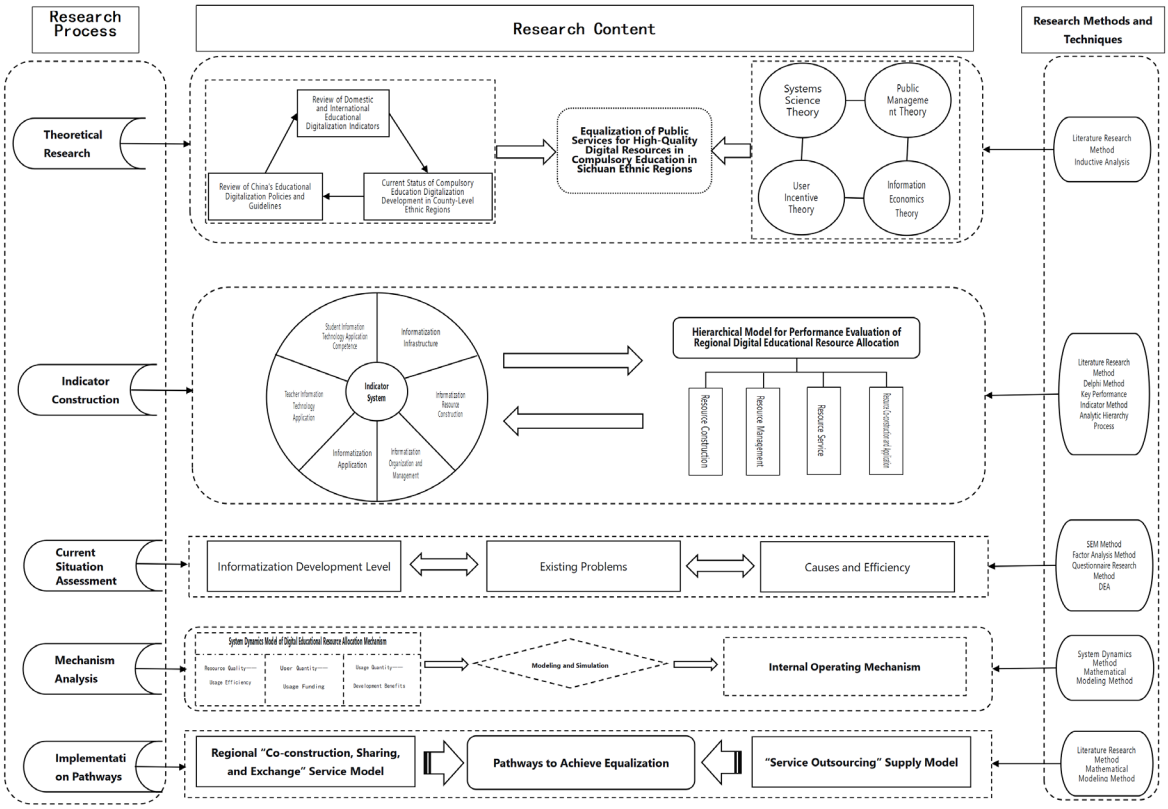


Figure 1. Research Methods and Technical Approach

The research methods and technical approach are primarily divided into five parts, as illustrated in Figure 1.

First, theoretical research. Based on systems science theory, public management theory, information economics theory, and user incentive theory, a theoretical framework for the research is constructed using literature research and inductive analysis methods.

Second, indicator construction. By reviewing domestic and international indicators for education digitalization and relevant Chinese policies and guidelines, performance evaluation indicator systems for regional digital educational resource allocation are constructed employing the Delphi method, key performance indicator (KPI) method, analytic hierarchy process (AHP), structural equation modeling (SEM), and factor analysis.

Third, current situation assessment. Focusing on the current state of compulsory education digitalization at the county level in the ethnic regions of Sichuan, this phase assesses the development levels and existing issues in areas such as teachers' application of information technology, information infrastructure, resource development, students' information technology application skills, and organizational management and application. Assessment and analysis are conducted using questionnaire research and data envelopment analysis (DEA), among other methods [17].

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Fourth, mechanism exploration. By constructing a system dynamics model for digital educational resource allocation, this phase analyzes the relationships between resource quality, user quantity, usage volume and efficiency, funding, and development benefits. Utilizing mathematical modeling and simulation methods, it aims to reveal the causes, efficiency issues, and internal operational mechanisms behind the unequal allocation of high-quality digital resources in compulsory education within the ethnic regions of Sichuan.

Finally, implementation pathways. This phase aims to establish a service model of "co-construction, sharing, and exchange" and a supply model of "service outsourcing" for high-quality digital educational resources in regional compulsory education. It proposes specific pathways to promote service equalization. Throughout this process, literature research and mathematical modeling are primarily used for scheme design and demonstration.

3.2 Design of Research Steps

Step One: Construction of the Performance Evaluation Indicator System and Assessment Hierarchy Model. This part focuses on constructing the performance evaluation indicator system for the digitization of compulsory education in ethnic regions and the hierarchical model for assessing the performance of regional digital educational resource allocation. This phase employs literature research, the Delphi method, key performance indicators (KPIs), and the analytic hierarchy process (AHP). From an "input-output" performance perspective, a performance evaluation indicator system is constructed across six dimensions: information infrastructure, information resource development, information organization and management, information application, teachers' application of information technology, and students' information technology application skills [18]. Furthermore, criteria and sub-criteria layers are established based on aspects such as the co-construction, management, service provision, sharing, and application of digital educational resources.

Step Two: Survey of the Basic Situation. This part investigates the basic status of digital educational resource allocation for compulsory education in the ethnic regions of Sichuan. This phase utilizes structural equation modeling (SEM), factor analysis, questionnaire surveys, and data envelopment analysis (DEA). Using the performance evaluation tool designed in the previous step, the study selects a total of six compulsory education schools—one primary and one junior high school each from W County in Aba Tibetan and Qiang Autonomous Prefecture, K City in Ganzi Tibetan Autonomous Prefecture, and X City in Liangshan Yi Autonomous Prefecture in Sichuan Province—for investigation. It describes and analyzes three aspects of these schools: their level of informatization development, problems encountered in optimizing digital educational resource allocation, and the causes and efficiency (technical efficiency, comprehensive efficiency, scale efficiency) behind the unequal allocation of high-quality digital resources.

Step Three: Construction of the System Dynamics Model and Policy Simulation. This part involves constructing a system dynamics model and conducting policy simulations for the allocation mechanism of high-quality digital educational resources in the ethnic regions of Sichuan. This phase employs system dynamics methods and mathematical modeling. A system dynamics model is constructed from three perspectives: "resource quality – usage efficiency," "user quantity – allocated funding," and "usage volume – development benefits" [19]. Policy simulations are then conducted to explore the internal operational mechanisms for optimizing digital resource allocation in compulsory education within Sichuan's ethnic regions.

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Step Four: Proposal of Pathways to Achieve Equalization. This part proposes pathways to promote the equalization of high-quality digital resource services for compulsory education in the ethnic regions of Sichuan. Building upon the policy simulations conducted in the previous step, this phase employs literature research and mathematical modeling. It aims to construct a regional service model of "co-construction, sharing, and exchange" and a supply model of "service outsourcing" for high-quality digital educational resources in compulsory education within Sichuan's ethnic regions. Subsequently, it proposes technology-supported pathways to achieve equalization in compulsory education digital resource services.

4. Results and Discussion

4.1 Proposed Construction Model of the Compulsory Education Informatization Performance Evaluation Indicator System for Ethnic Regions in Sichuan

Table 1. Performance Evaluation Indicator System for Compulsory Education Informatization in Ethnic Regions of Sichuan

First-level Indicator	Second-level Indicator
A1. Resource Construction	Informatization Infrastructure
	Informatization Resource Construction
A2. Resource Management	Informatization Organization & Management
	Performance Evaluation Indicator System
A3. Resource Service	Teacher IT Application
	Student IT Application Competence
	Informatization Application
A4. Resource Co-construction & Application	Internal Operating Mechanism
	Regional “Co-construction, Sharing, Exchange” Service Model

The construction model of the performance evaluation indicator system for compulsory education informatization in the ethnic regions of Sichuan is primarily built around 4 first-level core indicator dimensions and 9 second-level indicator dimensions (as shown in Table 1).

First, the Resource Development Indicator Dimension. This dimension focuses on the "hardware" and "content" foundations of digital education, specifically comprising two parts: information infrastructure (such as networks and terminal equipment) and the development of information resources (including digital courses and subject tool libraries).

Second, the Resource Management Indicator Dimension. This dimension emphasizes the "institutions" and "standards" of resource allocation. It primarily ensures the standardization and measurability of resource development and utilization through information organization and management (such as management bodies and systems) and the performance evaluation indicator system itself.

Third, the Resource Service Indicator Dimension. This dimension measures the practical "application"

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effectiveness of digital resources and the environment, which is concretely reflected in teachers' information technology application capabilities, students' information technology application skills, and the overall level of information technology application.

Fourth, the Resource Co-construction and Application Indicator Dimension. This dimension focuses on the "mechanisms" and "models" for sustainable development. It primarily examines regional service models of "co-construction, sharing, and exchange," as well as the internal operational mechanisms that ensure the sustained vitality and efficacy of resources [20].

Meanwhile, to ensure the scientific applicability of the constructed indicator system, the research team chose to conduct an empirical test of the informatization performance evaluation at X Primary School and Y Middle School in W County, Aba Tibetan and Qiang Autonomous Prefecture, Sichuan Province. Based on the indicator construction and empirical testing processes of this study, a reference model for the compulsory education informatization performance evaluation indicator system in the ethnic regions of Sichuan has been established.

4.2 Investigation Results and Discussion on the Development Level of Compulsory Education Informatization in Ethnic Regions

Over the past five years, Sichuan Province has focused on promoting the equitable allocation of high-quality digital resources for compulsory education in ethnic regions, successively issuing a series of policy documents such as the *Sichuan Province Education Informatization 2.0 Action Plan*, the *Sichuan Province Ten-Year Action Plan for Education Development in Ethnic Regions (2021–2030)*, the *Sichuan Province 14th Five-Year Plan for Education Development*, and the Implementation Opinions on Deepening the Development of "Internet + Education" in Ethnic Regions. Concurrently, effective measures have been continuously implemented in areas including regional infrastructure, digital resources, teachers' digital literacy, and teaching models. Efforts have included tackling the "Broadband Network Connectivity for Every School" initiative, raising the broadband access rate for primary and secondary schools in ethnic regions from 85% in 2019 to over 98% by 2023; equipping remote teaching sites with satellite receiving equipment or mobile learning terminals; establishing the "Sichuan Cloud Education" platform to deliver bilingual courses and high-quality lesson examples to schools in ethnic regions; implementing the "Special Training on Information Technology for Teachers in Ethnic Regions," cumulatively training over 30,000 teacher-trainees; promoting the "Three Types of Classrooms" (delivery classrooms, master teacher classrooms, and online classrooms from prestigious schools) to address teacher shortages in small-scale schools in ethnic regions; and piloting "Smart Education Demonstration Zones" in areas like Ganzi and Liangshan to explore data-driven precision teaching. By the end of 2023, achievements included: 98.5% of schools in ethnic regions achieving broadband access of 100 Mbps or higher; multimedia classroom coverage reaching 95%; the "Sichuan Cloud Education" platform benefiting over 500,000 students in ethnic regions; and an 88% pass rate on teachers' information technology application ability assessments.

Meanwhile, through an investigation into the development level of education informatization in compulsory education schools within this region, the research team identified some persistent issues. Specifically:

First, there is a noticeable disconnect between infrastructure and application effectiveness. The survey re-

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vealed that while the coverage of multimedia classrooms and teaching platforms in primary and secondary schools in ethnic regions has seen preliminary improvement, application efficiency remains low. Only 31.54% of multimedia classrooms are frequently used, and platforms often remain in a state of "built but not utilized." This reflects that informatization construction is still in a phase of "emphasizing hardware over application." The root cause lies in the lack of localized, high-quality digital educational resources that align with the actual teaching needs of ethnic regions, coupled with insufficient recognition among teachers and students of the pedagogical value of digital resources. Consequently, technology deployment has not been effectively integrated into daily teaching practices. Therefore, establishing a demand-oriented resource development mechanism and incorporating application effectiveness into school evaluations are effective measures to promote the integration of technology into classroom instruction.

Second, a weak support system hampers sustainable operation. The study found that education informatization institutions in compulsory education schools in ethnic regions are underdeveloped, with a shortage of professional technical personnel and relatively insufficient dedicated instructional guidance teachers in rural schools [21]. In contrast, there is a strong demand among teachers for training on integrating information technology with the curriculum. This indicates that the current support system struggles to ensure the continuous maintenance and deep application of informatization equipment, and teacher training often fails to address the practical educational and teaching context of ethnic regions. It is necessary to improve the construction of technical support teams at both county and school levels and to implement "embedded," scenario-based teacher training and research to overcome the dilemma of "someone builds it, no one manages it, and no one knows how to use it" [22].

Third, insufficient digital literacy and an imbalanced resource ecosystem. The ability of teachers and students to search for and access high-quality digital resources is generally low, students lack initiative in usage, and there is a significant gap in resource sharing willingness between urban and rural teachers and students. This highlights how weak digital literacy limits the accessibility of high-quality digital resources, while the lack of a resource sharing mechanism exacerbates the formation of "resource silos." The underlying reasons include a lack of cultural adaptability in resource content and the absence of a community culture that incentivizes sharing. Efforts are needed to focus on developing localized, high-quality digital educational resources and to build a new regional collaborative ecosystem for high-quality digital resources in compulsory education through mechanisms like urban-rural partnerships and online communities.

4.3 Analysis of Digital Resource Allocation Efficiency Based on DEA

This study employed the output-oriented BC^2 model to evaluate the allocation performance of high-quality digital resources in compulsory education within ethnic regions of Sichuan. The model assumes the existence of n decision-making units (DMUi, i=1,2,...,n). Each unit has k inputs and m outputs, with the input and output vectors denoted as X and Y respectively. Input slack variables (SA) and output slack variables (SB) are introduced. The model outputs include: comprehensive efficiency (θc), pure technical efficiency (θv), and scale efficiency (θs). When $\theta s = \theta n$, it indicates constant returns to scale. If $\theta s \neq \theta n$, the production process exhibits variable returns to scale. Pure technical efficiency (θv) reflects a DMU' s ability to achieve maximum output given its inputs: when $\theta v = 1$ and all slack variables are zero (SA=SB=0), the DMU is considered strongly efficient, indicating the digital resource allocation has reached relative optimality. If $\theta v = 1$ but non-zero slack

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variables exist (SA≠0 or SB≠0), the unit is deemed weakly efficient, suggesting room for structural improvement in resource allocation. If θv<1, it indicates the DMU's allocation efficiency has not reached the effective frontier, signifying significant potential for improvement.

Utilizing Deap software, this study analyzed the digital educational resource allocation efficiency of three areas—X City, W County, and K City—within Sichuan's ethnic regions from the perspectives of comprehensive efficiency, technical efficiency, and scale efficiency (see Table 2). The findings are as follows:

Firstly, regarding technical efficiency results, among the three surveyed areas, only W County in Aba Tibetan and Qiang Autonomous Prefecture achieved a technical efficiency score of 1, with both SA and SB equal to 0, indicating an effective DMU. In contrast, X City in Liangshan Yi Autonomous Prefecture and K City in Ganzi Tibetan Autonomous Prefecture scored below 1, signifying that these DMUs are ineffective, with inputs and outputs not in an optimal state.

Secondly, concerning comprehensive efficiency results, all three areas (X City, W County, K City) scored 1, with zero input-output redundancy, indicating effective digital resource allocation and demonstrating that input factors contribute positively to the allocation process.

Thirdly, examining scale efficiency results: Generally, total returns to scale increase with additional inputs. Under conditions of decreasing returns to scale, it is necessary to consider the input status of smaller-scale production units from an input perspective, and the input status of larger-scale units from an output perspective. W County exhibited constant returns to scale, suggesting its production units are seemingly in an optimal state. However, X City and K City are in phases of increasing and decreasing returns to scale, respectively. This indicates disparities and variations in inputs across different regions within Sichuan's ethnic areas, highlighting the need to prioritize optimizing the allocation of high-quality digital resources in compulsory education schools across these diverse regions.

This study further analyzed the correlation between scale efficiency and regional socio-structural variables. Test results show that scale efficiency has a statistically significant negative correlation with the proportion of the ethnic minority population ($p < 0.05$), suggesting that areas with higher concentrations of ethnic minority populations tend to have relatively lower scale efficiency in digital educational resource allocation. Simultaneously, scale efficiency shows a statistically significant positive correlation with the urbanization rate ($p < 0.01$), meaning that regions with higher urbanization levels typically demonstrate higher scale efficiency, while areas with concentrated rural populations exhibit markedly lower scale efficiency.

Collectively, these results indicate that in areas with concentrated ethnic minority populations and rural regions of Sichuan, the current allocation of high-quality digital educational resources for compulsory education has not yet achieved optimal scale benefits, and significant potential for efficiency improvement remains. This likely reflects a structural mismatch between the allocation mechanisms for high-quality digital educational resources and the actual local needs, or constraints imposed by factors such as infrastructure, usage capabilities, and support systems. Therefore, future policies should focus on enhancing the precision and suitability of resource allocation in these areas, promoting effective expansion and deep utilization of high-quality digital educational resources in compulsory education schools within ethnic and rural regions through differentiated investments and capacity building.

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Table 2. Analysis of High-Quality Digital Resource Allocation Efficiency in Compulsory Education for Ethnic Regions of Sichuan Based on DEA

Region Name	Technical Efficiency	Comprehensive Efficiency	Scale Efficiency	Returns to Scale	Input-Output Redundancy	Non-DEA Unit Weight	Ethnic Minority Population Proportion (%)	Urbanization Rate (%)
X City	0.993	1.000	0.993	drs	0.00	1.000	13.73	71.05
W County	1.000	1.000	1.000	-	0.00	1.000	7.98	45.58
K City	0.910	1.000	0.910	irs	0.00	1.000	10.38	31.49

4.4 Construction of System Dynamics Model and Policy Simulation

4.4.1 Construction of the System Dynamics Model

Based on the fundamental principles of system dynamics modeling, this study constructed a system dynamics model for analyzing resource quality and user usage behavior. During the model construction, key core variables such as resource quality, resource utilization rate, user base, total funding, and its allocation ratio were incorporated. To simplify the system boundary and highlight the primary driving mechanisms, factors including government funding sources, corporate competitive behavior, internal corporate technology and management levels, and the specific usage processes of teachers and students were designated as secondary factors. Furthermore, relationships such as the allocation balance between information construction costs and resource usage costs in compulsory education schools, as well as government digital resource procurement processes, were reasonably simplified.

The constructed model comprises a total of 26 variables, detailed as follows: 5 state variables, including single-resource click volume, current user count, potential user count, resource development investment cost, and resource usage investment cost; 3 rate variables, including click rate, user conversion rate, and cost conversion rate; 8 auxiliary variables, such as actual sharing degree, resource usage ratio correction coefficient, and utilization incentive regulation parameter; and 10 constants, covering parameters like quality improvement cycle, average user exposure rate, and environmental impact factor.

4.4.2 Policy Simulation Based on Vensim

Based on the Vensim simulation platform, this study constructed a system dynamics model to analyze the impact mechanisms of different policy variables on the utilization rate of digital educational resources. The simulation experiments primarily unfolded from the following four dimensions:

First, the dynamic impact of environment and user base on resource utilization. Simulations indicate that an increase in user exposure rate effectively promotes the conversion of potential users into actual users, thereby significantly improving resource utilization. Expanding the current user base also has a positive driving effect. However, as the pool of potential users is rapidly depleted, the utilization rate shows a declining trend in the later stages of the simulation. This suggests that educational institutions should establish long-term plans for resource renewal and user expansion to maintain the sustainability of resource utilization.

Second, the impact of resource development costs on resource quality and utilization. As resource development technology matures and costs decrease, the profit margin for developers relatively expands, incentivizing them to continuously improve resource quality. The stable supply of high-quality resources significantly

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promotes utilization. Simulation results also indicate that during the initial deployment phase of resources, the quality level has a critical impact on long-term usage rates; insufficient initial quality can easily lead to user attrition.

Third, the policy effects of usage costs in a market competition environment. The study found that moderately increasing resource usage fees actually contributes to higher utilization rates, with single-resource click volume showing a continuous growth trend. In contrast, low-cost or free models, while accelerating user growth in the short term, tend to decay quickly and struggle to foster sustained usage behaviors. This demonstrates that a reasonable pricing mechanism helps maintain user motivation and the long-term perceived value of resources.

Fourth, the moderating effect of user incentive strategies on usage willingness. Simulation results show that effective incentives not only need to stimulate usage motivation but should also shape users' stable expectations regarding resource value—specifically, the conviction that using the resource can tangibly enhance teaching efficiency and quality. Therefore, incentive design should transcend triggering short-term behaviors and shift towards constructing a long-term expectation system directly linked to teaching improvement.

5. Conclusion

5.1 The Optimization of High-Quality Digital Resource Allocation for Compulsory Education as a Systematic Project

In the ethnic regions of Sichuan, the optimal allocation of high-quality digital resources for compulsory education constitutes a project marked by significant systemic complexity. This system is composed of allocation agents, allocation objects, and external environmental factors, forming a multi-layered interactive network among these elements. Its structure exhibits multiple characteristics: Firstly, complexity, manifested in the interweaving of resource demands and supply pathways between urban and rural areas, as well as among schools. Secondly, hierarchical nature, requiring coordinated advancement of resource allocation at three levels: regional, county-wide, and school-based. Thirdly, dynamic nature, where technological iterations, changes in user base, and policy adjustments all contribute to the ongoing evolution of the system's state. Fourthly, gradual progression, constrained by the current state of infrastructure and digital literacy in ethnic regions, the improvement of digital educational resource allocation efficiency often requires cumulative and iterative processes. Fifthly, holism, where deficiencies in any single link may constrain the overall allocation efficiency, as evidenced by phenomena revealed in earlier surveys, such as "high hardware coverage but low application rates," which reflect insufficient synergy among system elements. Therefore, optimization must go beyond piecemeal adjustments. It requires a systems thinking approach to holistically plan the roles of agents, the structure of objects, and environmental support, thereby constructing a sustainable ecosystem for resource allocation.

5.2 The "Co-Construction, Sharing, and Exchange" Collaborative Allocation Model as a Viable Effective Pathway

To address the challenge of unequal allocation of high-quality digital resources for compulsory education in

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ethnic regions, the "Co-construction, Sharing, and Exchange" collaborative allocation model offers an institutionalized pathway. This model emphasizes multi-agent participation in resource development, cross-regional sharing of high-quality resources, and a demand-based resource exchange mechanism. Its effectiveness stems from three aspects: First, it can integrate dispersed resource development capacities within a region, reducing redundant investment through co-construction, which is particularly suitable for the realities of limited funding and technical capacity in ethnic regions. Second, the sharing mechanism, facilitated by platforms like "Sichuan Cloud Education," can extend high-quality resources from urban areas to rural and pastoral regions, alleviating spatial imbalances in resource distribution. The gap in resource sharing willingness between urban and rural areas observed in previous surveys precisely indicates the need to enhance sharing initiative through institutional design. Third, the exchange mechanism grants schools and teachers a degree of choice over resources, prompting the resource supply to better align with actual teaching needs, thereby improving resource utilization rates. Simulation studies also indicate that user exposure rate and sharing incentives significantly affect the sustainability of resource use. Therefore, this model is not merely a technical pathway but also an institutional innovation that promotes educational equity and stimulates endogenous fluidity of resources, contributing to the gradual achievement of equitable coverage of high-quality digital resources in compulsory education within ethnic regions.

5.3 The "Service Procurement" Mechanism Drives Changes in Resource Development Philosophy and Management

Exploring the implementation of a "service procurement" mechanism for high-quality digital resources in compulsory education within Sichuan's ethnic regions is conducive to transforming the methods of allocating high-quality digital educational resources and, more importantly, to fostering systematic changes in the philosophy of educational resource development and management thinking. This mechanism, through contractual relationships, clarifies quality standards, service requirements, and responsibilities for continuous improvement, effecting a shift from "administrative allocation" to "preferential access": First, it establishes a performance-based resource entry and exit mechanism, compelling suppliers to focus on teaching effectiveness and avoid the disconnect between resource development and usage. Second, service procurement typically includes dynamic evaluation and feedback clauses, providing institutional safeguards for the continuous improvement of resource quality—simulation studies also found that the initial quality of resource deployment critically impacts its long-term utilization rate. Third, this mechanism pressures education management departments to transition from direct providers to standard-setters, process supervisors, and outcome evaluators, promoting managerial professionalism. In ethnic regions, this transformation is particularly crucial—it helps break the closed cycle of resource development. Through open competition, process monitoring, and results-oriented approaches, it ensures that public investment is genuinely translated into high-quality, usable, and effective digital educational resources, thereby fundamentally promoting the balanced enhancement of compulsory education quality.

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