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Educational Equity under the Digital Divide: Online Education in Rural Areas of Developing Countries

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Abstract: This study focuses on the core issue of "educational equity under the digital divide," examining online education challenges in rural developing countries. With global online education users growing from 860 million in 2019 to 2.12 billion by 2025, the penetration rate gap between high-income and low-income countries widened from 39.4 percentage points to 59.2 percentage points, indicating that online education expansion has not automatically narrowed the digital divide. Through analyzing access disparities and usage disparities, the study systematically identifies infrastructure bottlenecks and capability gaps in rural online education, revealing multidimensional impacts of the digital divide on educational equity. Research findings demonstrate that the digital divide transcends mere technological access disparities, representing systemic inequalities embedded within social structures that directly manifest as fundamental fractures in educational equity across three dimensions: starting point fairness, process fairness, and outcome fairness. In rural developing countries, these fractures exhibit a "triple overlap" characteristic: physical infrastructure deficiencies, human capital capacity gaps, and symbolic cultural disconnections collectively form insurmountable structural barriers to educational equity. Multidimensional analysis of digital divide manifestations reveals that low-income countries score higher across all three dimensions (78.6-85.7 points) with progressively widening gaps, highlighting cumulative effects where early-stage disadvantages amplify over time. Access disparities create unequal starting points, usage disparities lead to process inequities, while achievement gaps result in outcome disparities. The study provides empirical evidence for formulating targeted intervention strategies and promoting educational equity under the digital divide.

Keywords: Digital divide; Educational equity; Online education; Rural education; Developing countries.

1. Introduction

1.1. The Marginalization of Rural Areas in Global Online Education Expansion

Global online education has experienced rapid growth over the past decade. According to International Telecommunication Union (ITU) statistics, the number of global online education the number of users was approximately 860 million in 2019 and is projected to rise to 2.12 billion by 2025, representing a growth of 146.5% over six years. The number of mobile learning users increased from 640 million to 18.6 亿, accounting for over 85% of total online education users. In developing countries, mobile learning, due to its relatively lower device requirements, has become the primary way for rural areas to access online education. However, the benefits of this expansion are distributed very unevenly across regions. The penetration rate of online education in high-income countries increased from 54.3% in 2019 to 73.8% in 2025, while in low-income countries it only increased slightly from 14.9% to 14.6% during the same period. The gap between the two widened from 39.4 to 59.2 percentage points.

The global trends and regional disparities in the expansion of online education. In terms of user scale, the number of global online education users continues to grow. However, the penetration rate gap between high-income and low-income countries is widening, expanding from 39.4 percentage points in 2019 to 59.2 percentage points in 2025. This trend indicates that the expansion of online education has not automatically narrowed the digital divide; instead, it has exacerbated educational inequality to some extent. The marginalized status of rural areas is particularly pronounced. For example, in Sub-Saharan Africa, the average online education usage rate in 12 countries is only 11.4%, with Malawi as low as 3.4%. The situation in South Asia is slightly better, but the average coverage rate is still less than 15%, and the rural internet access rate is only 28.2%. Research by Zhang Xin, based on national data from 2009-2018, shows that although the urban-rural digital divide is generally narrowing, the internal structure is highly uneven, with significant improvements in the access dimension of information technology, but fluctuating and slow progress in the application and environmental dimensions of information technology [1]. Hu Angang points out that while China has successfully narrowed the digital divide with developed countries and significantly reduced the urban-rural digital divide, the global digital divide remains a severe challenge [2]. Yalalem Assefa, from a social justice perspective, argues that the digital divide exacerbates existing educational inequalities in higher education, leading to the reproduction of automated inequality for marginalized groups [3]. This effect is equally significant in basic education. Rural students face multiple barriers such as difficulties in network access, lack of equipment, and insufficient digital literacy, making it challenging to fully participate in online learning. Degwale Gebeyehu Belays analysis of rural stu dents in Ethiopia reveals that national online teaching programs, due to a lack of consideration for the actual access conditions of rural students, have essentially created new educational exclusions [4].

1.2. The Profound Impact of the Digital Divide on Educational Equity

The digital divide is not merely a disparity in technological access but a systemic inequality embedded within social structures, which in the field of education directly translates into profound fractures in educational opportunities, processes, and outcomes. Wei Tao, starting from the theory of educational equity, points out that the pursuit of educational equity has gradually shifted from extensive fairness to the characteristic development of intensive fairness, moving from the pursuit of equality in starting points to equality in processes and outcomes [5]. Zhang Liyongs field research on two rural primary schools in D County, Linxia Prefecture, Gansu Province, reveals that teacher shortage and weak information literacy have become the core bottlenecks restricting the effectiveness of English teaching. Teachers not only lack access to quality digital resources but also commonly lack the ability to effectively integrate technology tools into the logic of subject teaching [6]. Zhang Jiaping s research confirms that the digital divide is particularly pronounced among people with poor health status, advanced age, and low income and education levels, forming a typical multiple disadvantages stacking effect [7]. In the context of rural education, this manifests as intertwined issues such as the lagging digital skills of elderly teachers, the lack of equipment for students from poor families, and the digital access barriers faced by children with disabilities. Liu Cuixia's concept of digital int egration differences goes beyond the static dichotomy of having or not having and emphasizes the need to focus on the participation depth, behavior quality, and meaning construction abilities of different groups in the digital world [8]. When urban students use AI tools for project-based inquiry, rural students may still be at the stage of superficial engagement with pre-recorded videos. This difference in participation depth ultimately translates into inequality in educational outcomes. Yang Yiyuans analysis of the EUs digital competency framework f or educators indicates that the digital competency of educators is an important indicator for ensuring the effectiveness of online teaching [9]. Therefore, to bridge the digital divide and achieve educational equity, it is necessary to shift from a single access -oriented approach to a systemic intervention that integrates access -use-effectiveness.

1.3. Research Scope, Regional Focus, and Methodological Approach

This study focuses on the issue of online education in rural areas of developing countries, with a particular emphasis on the mechanisms and coping strategies of the digital divides impact on educational equity. Regionally, the study uses Sub-Saharan Africa and South Asia as core case regions. The selection of these two regions is based on a dual consideration. In terms of problem severity, they are the regions with the most severe global digital divide, with the average mobile internet penetration rate in 12 Sub-Saharan African countries being only 32.5%, and the average rural internet access rate in 5 South Asian countries being just 28.2%, with a gender digital divide as high as 29.0 percentage points. In terms of comparative research value, the two regions face both common and different challenges in the digitalization of education, facilitating comparative analysis. Sub-Saharan Africa faces more severe challenges in electricity supply (average access rate of 47.5%) and network infrastructure, with uneven 4G network coverage, while South Asias over all situation is slightly better but has prominent issues in the localization of educational content. Comparative analysis can provide empirical evidence for formulating targeted intervention strategies.

This study adopts a research approach that combines literature research with empirical data analysis. Through literature review, an analytical framework for the digital divide and educational equity is constructed, identifying three analytical dimensions: the access gap, the usage gap, and the effectiveness gap. Using publicly available data from authoritative institutions such as the International Telecommunication Union (ITU) and the United Nations Educational, Scientific and Cultural Organization (UNESCO), an empirical analysis is conducted on the current status of digital access, teachers digital skills, and rural education barriers in Sub-Saharan Africa and South Asia. Based on the above analysis, the multi-dimensional impact mechanism of the digital divide on educational equity is systematically revealed, and corresponding policy recommendations are proposed.

The scores for the three gaps in the text are synthesized from original indicators released by ITU, World Bank, and other institutions after standardization, using a 0–100 scale, where a higher score indicates a more severe level of inequality. The research approach follows a logical framework of phenomenon description—cause analysis—impact assessment—policy recommendations, striving to provide theoretical support and practical reference for bridging the digital divide from the perspective of educational equity.

2. Access Gap – Infrastructure Bottleneck for Rural Online Education

2.1. Network Coverage Gap

2.1.1. Low Mobile and Broadband Network Coverage in Remote Areas

Network coverage is a physical prerequisite for conducting online education, but in rural areas of developing countries, this prerequisite is far from being met. ITU data for 2025 shows that the rural internet access rate in low-income countries is only 13.7%, with a gap of 28.6 percentage points compared to urban areas. The issue of insufficient network coverage is particularly pronounced in Sub-Saharan Africa, where the average 4G coverage rate in 12 countries is only 65.2%, with blind spots concentrated in remote areas with sparse populations and complex terrain. From a technological generational perspective, the deployment of 5G networks shows a rich countries first characteristic, with high-income countries achieving a 5G coverage rate of 84.2%, while low-income countries only reach 3.9%, resulting in a staggering gap of 80.3 percentage points. Zhang Jie used the difference-in-differences method to confirm that the Broadband China pilot significantly boosted urban innovation levels, with the core mechanism being the enhancement of network connectivity for knowledge flow and collaborative innovation [10].

Figure 1 illustrates the comparison of different income level countries across multiple dimensions of the digital divide. In terms of internet penetration rate, high-income countries have reached 92.6%, while low-income countries are only at 21.7%, a gap of 70.9 percentage points. The urban-

rural gap is particularly pronounced in low-income countries, with urban internet penetration at 40.3% compared to just 13.7% in rural areas. The disparity in 5G coverage is even more stark, with high-income countries at 84.2% and low-income countries at only 3.9%. In terms of broadband affordability, mobile data costs in low-income countries account for a staggering 24.6% of per capita GNI, far exceeding the 1% affordability target set by the UN Broadband Commission.

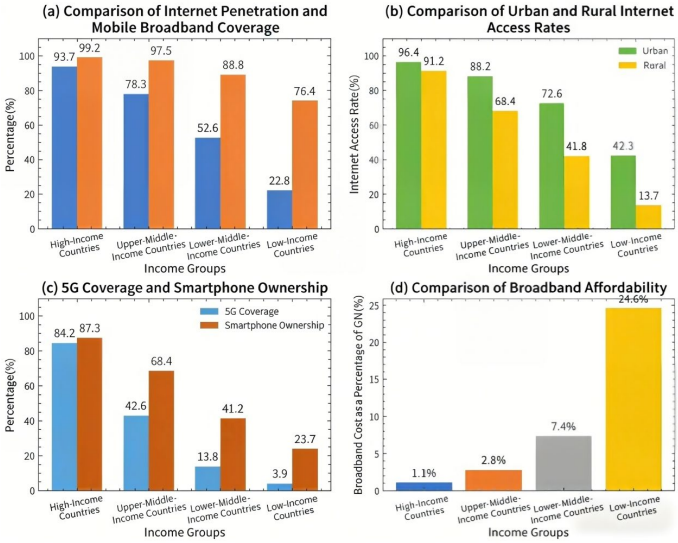

Figure 1. Multidimensional Comparison of the Global Digital Divide

2.1.2. High Network Tariffs Deter Household Usage

Even when network coverage is in place, high tariffs remain a significant barrier to rural households use of online education services. ITU data shows that mobile data costs in low-income countries account for a staggering 24.6% of per capita GNI, significantly surpassing the 1% affordability target set by the UN Broadband Commission. In high-income countries, this figure is only 1.1%, a difference of 22.4 times. This means that in low-income countries, an average household would need to spend nearly a quarter of their annual income to afford basic mobile data services. The continuous and stable data connection required for online education remains an unattainable luxury for most rural households. The affordability of network tariffs is particularly severe in Sub-Saharan Africa and South Asia, where the average mobile data cost as a percentage of income in 12 Sub-Saharan African countries reaches 18.3%. Qin Wenjins research has verified the positive driving effect of digital infrastructure on the development of the digital economy[11].

2.1.3. Typical Challenges in Sub-Saharan Africa and South Asia

Sub-Saharan Africa and South Asia are two of the most challenging regions globally in terms of the digital divide, presenting both commonalities and differences in their network coverage challenges. The average mobile Internet penetration rate in 12 Sub-Saharan African countries is 32.5%, with significant internal disparities, ranging from 68.4% i n South Africa to just 10.7% in Niger. The regions core challenge lies in the severe inadequacy of infrastructure, with an average 4G coverage rate of 65.2%, meaning more than one-third of the population lacks access to basic mobile broadband services. In South Asia, the average mobile Internet penetration rate is 39.2%, with a rural Internet access r ate of only 28.2%. Compared to Sub-Saharan Africa, South Asias network infrastructure is slightly better overall, but the gender digital divide is more pronounced, averaging 29.0 percentage points.

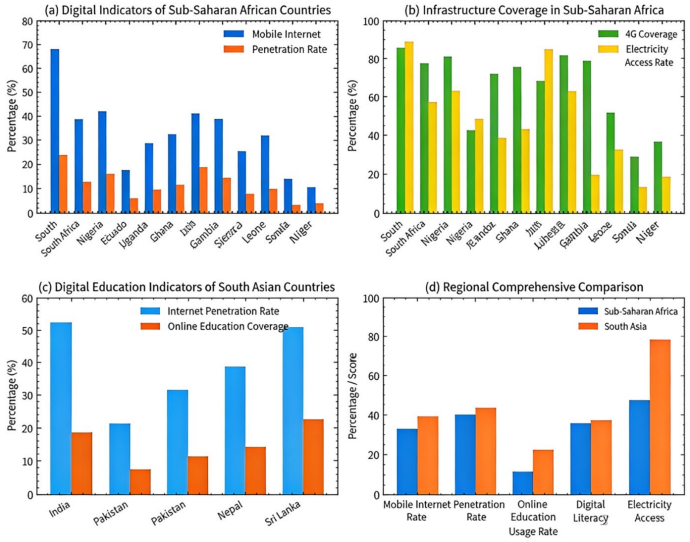

Figure 2. Comparison of Digital Education Status in Sub-Saharan Africa and South Asia

Figure 2 visually presents the differences in key digital education indicators between two regions. Sub-Saharan

Africa significantly lags behind in infrastructure indicators such aselectricity access rate and 4G coverage rate, with an average online education usage rate of only 11.4%. The overall situation in South Asia is slightly better, but the digital divide and low rural internet access rate remain prominent issues.

Table 1. Comparison of Digital Education Indicators between Sub-Saharan Africa and South Asia

Indicator	Sub-Saharan Africa	South Asia	Gap
Mobile Internet Penetration (%)	32.5	39.2	-6.7
Rural Internet Access Rate%)	21.7	28.2	-6.5
4G Coverage4G (%)	65.2	76.3	-11.1
Electricity Access Rate (%)	47.5	89.6	-42.1
Online Education Usage Rate (%)	11.4	16.8	-5.4
Gender Digital Gap (percentage points)	22.3	29.0	+6.7

2.2. Lack of Terminal Devices

2.2.1. Severe Insufficiency of Smartphone and Computer Ownership Rates

Terminal devices are essential tools for online education, but in rural areas of developing countries, ownership rates of these devices are severely insufficient. ITU data shows that the smartphone ownership rate in low-income countries is only 22.8%, while in high-income countries it has reached 89.3%, a gap of 66.5 percentage points. The gap in compute ownership rates is even more pronounced, with low-income countries at only 8.4% compared to 81.7% in high-income countries, a difference of 73.3 percentage points. The computers, tablets, and other terminal devices required for online education are an unaffordable expense for most rural families. The urban-rural gap in device ownership is also significant. For example, in China, while the smartphone penetration rate in rural areas has reached 68.2%, the computer ownership rate is only 19.3%, much lower than the urban rate of 61.7%. The small screens and touch input methods of smartphones limit the ability to complete complex learning tasks, making it difficult to effectively engage in learning content such as programming, document editing, and data analysis on mobile phones. Yang Bos research on the Digital Education Resource Coverage for Teaching Sites project found that while the project has played an important r ole in promoting the balanced development of compulsory education, the configuration and use of equipment in remote rural areas still face many challenges [12].

2.2.2. Device Sharing in Large Families Leads to Learning Conflicts

Another issue caused by device shortages is competition for learning resources within the household. Large families often have only one smart device, which must be shared among multiple children, leading to conflicts over learning time as children have to take turns using the device and cannot fully participate in online courses simultaneously. The practice of online teaching during the pandemic fully exposed this problem, with children in large families often only able to have one child participating in online learning while others were forced to miss out. Device sharing also affects the quality of learning; when devices must be used in turns, each childs available learning time is compressed, making it difficult to engage in deep learning. During the busy farming season or when family chores are required, the device may be occupied by parents for communication or work, causing interruptions in childrens online le arning. This unstable device usage severely impacts the continuity and effectiveness of online learning.

2.2.3. Weak Operation and Maintenance Capabilities of Public Digital Facilities

Faced with the reality of insufficient household equipment, public digital facilities should play a supplementary role.

However, in rural areas of developing countries, the construction and maintenance of such facilities face severe challenges. The number of public access points such as digital community centers, rural internet cafes, and school computer labs is seriously inadequate, and they are mostly concentrated in township centers, making it difficult to cover remote villages. More critically, the limited number of existing public digital facilities struggles to operate effectively due to a lack of continuous investment. Issues like equipment aging, network failures, and lack of technical personnel for maintenance are widespread, rendering many public digital facilities zombie facilities. Ji Xuans multidimensional measurement of digital rural construction in Linan District, Hangzhou, shows that despite significant pilot achievements, problems such as low quality of village officials and talent shortages remain as last mile obstacles in implementation [13] .

2.3. Unstable Energy Supply

2.3.1. Frequent Power Outages Affect Continuity of Online Learning

A stable electricity supply is the cornerstone of digital technology operations, but in rural areas of developing countries, this cornerstone is extremely fragile. The average electricity access rate in 12 countries in Sub-Saharan Africa i s only 47.5%, with countries like Malawi and Niger having access rates of less than 20%. Even in areas with electricity coverage, the stability of power supply remains a significant issue, with frequent outages, voltage fluctuations, and power rationing policies making it difficult to sustain online learning. ITU surveys show that rural areas in Sub-Saharan Africa experience an average of 3 to 4 power outages per week, each lasting several hours, severely impacting the quality and continuity of online education. The impact of unstable electricity supply on online education is multifaceted; sudden outages may cause ongoing online classes to be interrupted, assignments to be lost, and exams to be suspended, leading t o confusion in learning progress and a loss of confidence. Fu Dajie points out that the low digital literacy and skill levels of farmers are important factors restricting the development of the rural digital economy, and the lack of infrastructure such as electricity further exacerbates this difficulty [14].

2.3.2. Limited Promotion of Renewable Energy Solutions

Facing the challenges of grid power supply, renewable energy sources such as solar and wind power are seen as viable solutions to address rural electricity issues. Hazim Shakhatrehs review highlights that drones and solar base stations can be rapidly deployed and flexibly networked, making them particularly suitable for emergency communications and educational support in remote areas. Some international organizations and companies are also promoting the Solar Schools project, which equips rural schools with solar power generation equipment to provide energy security for digital education [15]. However, the

promotion of renewable energy solutions in developing countries faces multiple obstacles. Cost is a primary barrier; although the price of solar panels is decreasing, the initial investment is still a significant expense for rural schools and impoverished families with meager incomes. Yong Zeng emphasizes that low-altitude UAV communication, due to its short-range line-of-sight link advantages, can provide better channel quality [16]. However, the deployment of such cutting-edge technologies also requires a localized technical support system.

2.3.3. Lack of Alternative Teaching Mechanisms Under Frequent Power Outages

When power outages become the norm, establishing effective alternative teaching mechanisms becomes particularly crucial. However, in most rural areas of developing countries, such mechanisms are almost non-existent. Schools lack backup power or offline teaching resources, teachers are not trained to handle sudden power outages, and students do not have alternative learning materials and plans. During power outages, teaching activities often come to a complete halt, only to start from scratch once power is restored, resulting in significant time waste and learning efficiency loss. Fernando Ferris analysis of emergency remote teaching during the pandemic indicates that effective educational technology integration requires a hybrid model combining high -tech and low -tech to ensure that basic teaching activities can be maintained under various infrastructure conditions [17].

2.4. Multidimensional Manifestations and Empirical Analysis of the Digital Divide

2.4.1. The First Divide – Unequal Access Opportunities

The first divide of the digital divide focuses on unequal access opportunities, meaning the disparities among different groups in obtaining material conditions such as network infrastructure, terminal devices, and electricity supply. Metrics to measure this divide include internet penetration rate, mobile broadband coverage, smart device ownership rate, and electricity access rate. Experimental data shows that low-income countries score 78.6 on the first divide, indicating a severe gap. High-income countries score only 12.4, with a difference of 66.2 points. The first divide is the most fundamental and visible form of digital inequality, directly determining the issue of whether access is possible. Wi thout network coverage, terminal devices, or electricity supply, any form of online education is impossible. From the perspective of educational equity, the first divide essentially constitutes an equity issue in educational starting points, meaning that rural students lack basic digital access conditions and cannot obtain the same educational opportunities as urban students.

2.4.2. The Second Digital Divide – Differences in Usage Ability and Skills

The second digital divide focuses on differences in usage ability and skills, which refers to disparities among different groups in digital literacy, technical usage ability, and information acquisition ability. Indicators to measure this divide include digital literacy scores, teacher digital skills mastery rate, and network usage depth. Experimental data shows that low-income countries score 82.4 on the second digital divide, while high-income countries score 18.6, a gap of 63.8 points. The second digital divide highlights the crucial issue that access does not equal usage. Even with internet access and devices, without the necessary digital literacy and usage skills, it is difficult to effectively leverage digital technology for learning. Yang Senwens empirical research based on CGSS2017 data indicates that the digital divide is particularly pronounced among those with poor health status, older age, and lower income and education levels, for ming a typical multiple disadvantage stacking effect [18] t. From the perspective of educational equity, the second digital divide constitutes an equity issue in the educational process, meaning that even with access to technology, rural students still cannot fully participate in online learning due to insufficient digital literacy.

2.4.3. The Third Digital Divide – Disparities in Educational Effectiveness and Outcomes

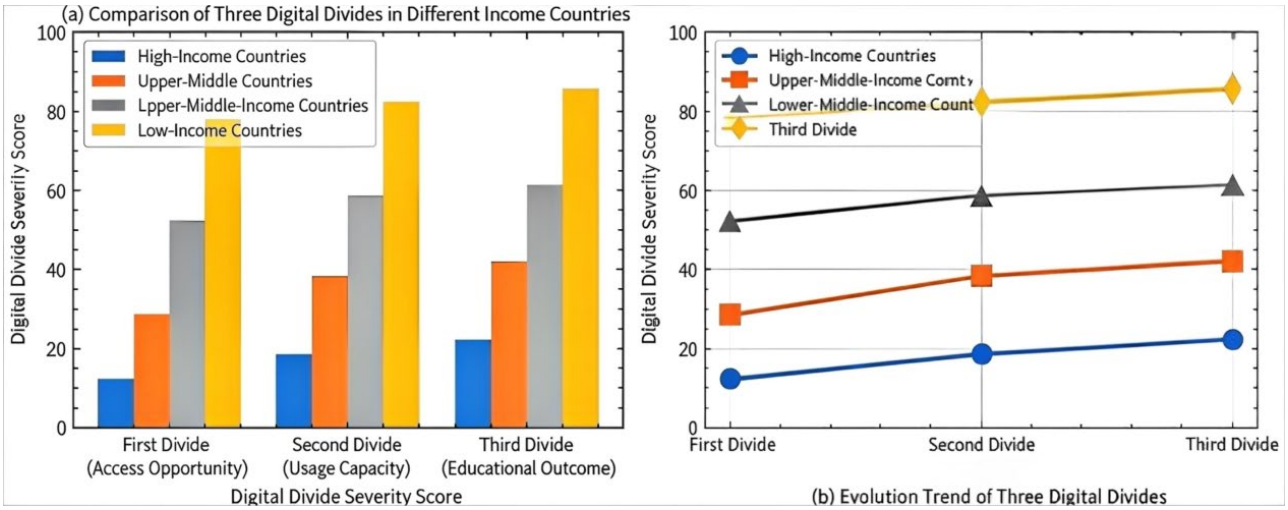

Figure 3. Multidimensional Manifestations and Empirical Analysis of the Digital Divide

The third digital divide focuses on disparities in educational effectiveness and outcomes, referring to the differences among various groups in terms of the actual benefits they derive from digital technology. Indicators to measure this divide include online learning effectiveness, educational outcome transformation, and the extent of digital dividend acquisition. Experimental data shows that low-income countries score as high as 85.7 points on this divide, making it the most severe of the three divides. This means that even after overcoming access barriers and usage barriers, rural students still struggle to achieve educational outcomes on par with their urban counterparts. Research by Shen Kunrong indicates that network infrastructure construction can stimulate corporate innovation, but in the education sector,

the transformation of digital infrastructure dividends also faces challenges [19]. From the perspective of educational equity, the third digital divide constitutes an equity issue of educational outcomes, meaning the digital divide ultimately hinders rural students from achieving the same educational effectiveness and development opportunities as urban students.

Table 2. Comparison of Digital Divide Scores Across Countries with Different Income Levels

Layer Type	Low-Income Countries	Lower-Middle-Income Countries	Upper-Middle-Income Countries	High-Income Countries
First Layer (Access)	78.6	52.3	31.7	12.4
Second Layer (Usage)	82.4	58.6	35.2	18.6
Third Layer (Outcome)	85.7	63.4	38.9	22.3

Figure 3 presents the performance of countries at different income levels across the three digital divides. This mpirical analysis reveals the deep impact mechanism of the digital divide on educational equity. From the perspective of low-income countries, the three divides show a trend of expanding layer by layer, increasing from 78.6 points for the first divide to 85.7 points for the third divide, a rise of 7.1 points. This cumulative divide effect indicates that the digital divide has a cumulative characteristic, where disadvantages in the early stages are amplified in subsequent stages. From the perspective of educational equity, this cumulative effect means that the unfairness at the starting point of education (access divide) will gradually evolve into unfairness in the educational process (usage gap), ultimately leading to inequity in educational outcomes (effectiveness divide). Chima Abimbola Eden emphasizes that effective technology integration requires aligning technology tools with teaching objectives, where technology tools must serve specific teaching objectives and learner needs [20].

3. Usage Gap – From Technical Access to the Capability Gap in Effective Learning

3.1. Teacher digital teaching skills are insufficient

3.1.1. Lack of online course design and platform operation training

Teacher digital teaching ability is a key variable for the effective implementation of online education, but in rural areas of developing countries, this variable is severely lacking. Han Xibins diagnosis of vocational education digital transformation points out that one of the biggest challenges is the urgent need to update and improve the connotation and level of teachers digital teaching ability [21]. Zhang Liyongs empirical research outlines the plight of rural teachers, who not only face pressure from an insufficient total number of teachers but also have dual shortcomings in the two dimensions of professional ability and information literacy. Joyce Pittmans action research in the context of emergency remote teaching during the pandemic revealed the complexity of teachers digital competenc e, which is not only about technical operation but also encompasses curriculum design, assessment reform, emotional connection, and other multi-dimensional abilities [22].

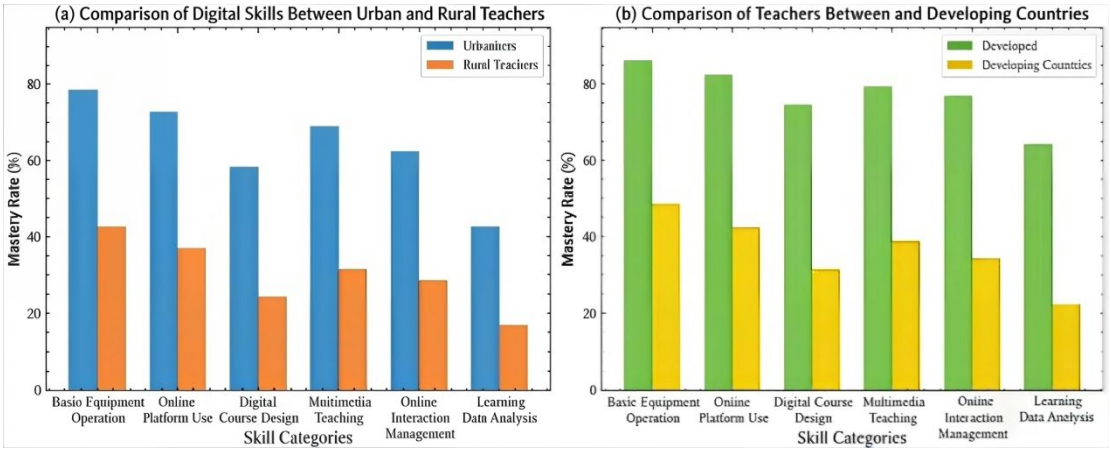

Figure 4. Teacher digital teaching skills gap

Table 3. Comparison of digital skills mastery rate between urban and rural teachers (%)

Skill Type	Urban Teachers	Rural Teachers	Urban-Rural Gap
Multimedia Teaching	68.7	35.2	33.5
Online Interaction Management	62.4	29.8	32.6
Platform Operation	71.3	38.6	32.7
Digital Course Design	58.2	24.7	33.5
Learning Data Analysis	54.6	22.3	32.3

Figure 4 shows multiple dimensions of the digital skills gap between urban and rural teachers. In terms of the overall gap, the average mastery rate for urban teachers is 63.9%, while for rural teachers it is 30.1%, a difference of 33.8 percentage points. In terms of specific skills, the gaps between urban and rural teachers in multimedia teaching, online interaction management, and platform operation are all over 30 percentage points. The gap between teachers in developed and developing countries is even more significant, with an average difference of 40.9 percentage points.

3.1.2. Traditional teaching model is difficult to transform into blended mode

The integration of digital technology into the education sector brings not only the update of technology tools but also

the restructuring of teaching models. The traditional teacher-centered classroom model needs to transform into a student-centered self-learning model in the online education environment. Javier Portillos post-pandemic survey of teachers in the Basque region of Spain revealed that even in developed countries, teachers generally perceive higher workloads and negative emotions due to insufficient digital skills training [23]. This finding serves as a warning that without a supporting digital literacy training system, the result of laying infrastructure in rural areas may be expensive infrastructure remaining in a dormant state for a long time. Huang Qiaohuis research on social media aging adaptation revealed a similar phenomenon: many rural teachers own smartphones but only use them for communication and social activities, failing to transition to professional scenarios such as instructional design [24].

3.1.3. The Absence of Rural Teacher Incentive Mechanisms Leads to Passive Technology Adoption

The improvement of teachers digital skills requires not only training and support but also effective incentive mechanisms. In rural areas of developing countries, the lack of teacher incentive mechanisms, low salaries, limited career advancement opportunities, and harsh working environments severely dampen teachers enthusiasm for learning and applying new technologies. Wu Qingqing captured the real anxieties of frontline teachers in her AI programming teaching practice in Ningxia elementary schools, where uneven course resources and high costs of teaching equipment led to significant compromises in policy implementation at the grassroots level [25]. Ke Qingchaos Fourfold Empowerment model for the National Smart Education Platform addresses this issue by focusing on connection empowerment and capacity empowerment, aiming to provide rural teachers with immediate, precise, and sustainable professional development support through the platform by bringing together experts, renowned teachers, and teaching researchers [26]. Shi Dongqing, from the perspective of Education Information 2.0, points out that achieving education modernization requires promoting informatization and intelligent teaching methods as well as the development and transformation of educational information [27].

3.2. Weak student self-directed learning support

3.2.1. Low digital literacy of family guardians, unable to provide tutoring

One of the key differences between online learning and traditional classroom learning is that the sources of learning support expand from school to the family. However, in rural areas of developing countries, family support is severely lacking. Anli Lis research on cultural reeducation reveals that the intergenerational transmission of digital skills does not occur uniformly, and the abundance of family digital capital directly determines whether students can obtain continuous, high-quality digital learning support [28]. This mechanism creates a negative cycle in rural areas, where low parental digital literacy makes it difficult to support childrens online learning, and childrens learning difficulties in turn undermine parents confidence and support for online education. The lack of family digital literacy is reflected in various aspects such as technical support, content support, and emotional support, leaving rural students in a more isolated situation in online learning.

3.2.2. Lack of Peer Interaction and Teacher Real-time Feedback Mechanism

A core challenge of online education is how to maintain learning interactions without face-to-face contact. Interactive forms like peer discussions, group collaborations, and instant Q&A in traditional classrooms are difficult to replicate in online environments. Rural students face even greater difficulties participating in synchronous online interactions due to device sharing and unstable networks. Lack of peer interaction not only affects learning effectiveness but also weakens learning motivation and a sense of belonging. Rural teachers, due to insufficient digital competence and limited time resources, struggle to provide timely and personalized learning feedback. Students submitted assignments may take days to be graded, and this delayed feedback severely impacts learning efficiency and effectiveness.

3.2.3. Psychological and Motivational Factors Exacerbate Dropout Risks

Online learning requires stronger self-regulated learning abilities and self-regulation skills, presenting a particular challenge for rural students. Without face-to-face supervision and support, students are more likely to feel lonely and neglected. Trans study in Vietnam found that students digital literacy is strongly correlated with their family economic status and parents education level, while the influence of school location (urban and rural areas) is relatively weak [29]. This finding reveals another issue: when family support is insufficient, the role of school support becomes particularly important. However, rural schools often lack the capacity to provide effective online learning support. Psychological and motivational factors are particularly critical in rural online education. Rural students may have lower expectations for education and are prone to losing interest due to technical difficulties and insufficient learning support. Gong Jings research shows that students self-regulated learning ability is a hot issue in the field of educational psychology. In the information age network environment, students have more autonomy but also face greater challenges [30].

3.3. Lack of Localization of Educational Content

3.3.1. Online Courses Are Mostly Developed in Urban Contexts and Mainstream Languages

Localization of educational content is the "Archimedean point" for solving the dilemma of educational equity under the digital divide. However, most current online educational resources are developed in urban contexts and mainstream languages, which are disconnected from the life experiences and cultural backgrounds of rural students. The core spirit of the digital teaching resource application methods such as "situational," "scenario-based," and "life-based" proposed by Zhang Liyong is "localization," anchoring abstract learning content in real scenarios familiar to students. Courses in urban contexts face multiple challenges in rural areas, as urban cases lack resonance with rural students, and standard language poses barriers for ethnic minority students. Zhang Wenyan pointed out that the development of digital teaching resources provides a good opportunity to promote the sharing of high-quality teaching resources between urban and rural areas and improve the quality of classroom teaching in rural schools [31]. Research by Ping Heguang shows that "Internet+Education" plays an important role in optimizing the allocation of educational resources and promoting educational equity [32].

3.3.2. Marginalization of Ethnic Minority Languages and Local Knowledge Systems

Rural areas in developing countries are often multilingual and multicultural, with ethnic minority languages and local knowledge systems being important components of the local culture. However, online education platforms often overlook this diversity, using the official language or common language as the primary language of instruction. Chima Abimbola Eden emphasizes that effective technology integration requires aligning technology tools with teaching objectives, meaning that technology tools must serve specific teaching objectives and learner needs. The education cloud service system envisioned by Ye Qiu Xu provides a technical framework for building a regional characteristic resource library, enabling local operas, folk crafts, local history, and other non-standardized knowledge to be digitized and incorporated into the teaching process [33]. Zhang Renjie points out that in the context of globalization, it is a major issue that education must face and address: how to base education on local culture while drawing on the advanced aspects of foreign teaching methods to create an educational model suitable for local characteristics [34].

3.3.3. Agricultural Cycles and Seasonal Labor Not Integrated into Learning Schedule Design

Rural life is closely connected to agricultural production, and it is common for students to participate in family labor during the busy farming season. However, the scheduling of online education often follows the urban school calendar without considering the agricultural cycles of rural areas. This misalignment makes it difficult for students to balance their studies and family labor during the busy farming season, leading to their absence from online courses. The impact of the agricultural cycle is also evident in internet usage, as students may need to use mobile devices for learning in the fields during the busy season, but network coverage in rural areas often cannot support outdoor learning.

Table 4. Main Manifestations of the Usage Gap in Rural Online Education

Divide Type	Main Manifestations	Impact Level
Teacher Competency Divide	Insufficient digital course design ability, lack of platform operation skills	High
Family Support Divide	Low parental digital literacy, inability to provide technical tutoring	High
Interaction/Feedback Divide	Lack of peer interaction, delayed teacher feedback	Medium
Content Adaptation Divide	Courses with urban context, lack of resources in minority languages	High
Time Rhythm Divide	Misalignment between agricultural cycles and academic calendar	Medium

4. Conclusion

4.1. Research Conclusions

This study, with educational equity under the digital divide as its core theme, focuses on online education issues in rural areas of developing countries and systematically reveals the multi-dimensional impact mechanism of the digital divide on educational equity. The research finds that the digital divide is not merely a difference in technical access, but a systemic inequality embedded in social structures, directly translating into profound fractures in education starting point equity, education process equity, and education outcome equity. In rural areas of developing countries, this fracture exhibits a triple overlap characteristic, where the physical absence of infrastructure, the capability deficiency of human capital, and the symbolic alienation of cultural context jointly constitute insurmountable structural barriers to educational equity.

At the level of education starting point equity, research reveals the severe infrastructure bottlenecks faced by rural areas in developing countries. The rural internet access rate in low-income countries is only 13.7%, with a gap of 28.6percentage points compared to urban areas. The 5G coverage rate in high-income countries has reached84.2%, while it is only3.9%in low-income countries, with a gap as high as 80.3 percentage points. The broadband costs in low-income countries account for a high proportion of per capita GNI at 24.6%, far exceeding the 1%affordability target set by the UN Broadband Commission. The average mobile internet penetration rate in 12countries in Sub-Saharan Africa is only 32.5%, the average electricity access rate is only47.5%, and the average online education usage rate is only 11.4%. In South Asia, the average rural internet access rate in 5 countries is only 28.2%, and the gender digital divide is as high as 29.0percentage points. Network coverage, terminal devices, and energy supply constitute the physical prerequisites for developing online education.

The affordability of network tariffs is another key obstacle. Low-income country households need to spend nearly a quarter of their annual income to afford basic mobile data services, making online education an unattainable luxury. The issue of unstable electricity supply is particularly prominent in Sub-Saharan Africa, where rural schools in the region experience an average of 3 to 4 power outages per week, severely affecting the continuity of online learning. These infrastructure barriers essentially deprive rural students of the basic right to access online education, resulting in inequity in educational starting point. At the level of education process equity, the study found that teacher digital teaching ability is a key variable for the effective implementation of online education, and this ability is severely lacking in rural areas of developing countries. The average mastery rate of digital skills among urban teachers is 63.9%, while for rural teachers it is only 30. 1%, a gap of 33.8 percentage points. Rural teachers mastery rates for advanced skills such as multimedia teaching, online interaction management, digital curriculum design, and learning data analysis are all below 30%. The low digital literacy of family guardians leads to students lacking self-directed learning support. Online courses are often developed with urban contexts and mainstream languages, while ethnic minority languages and local knowledge systems are marginalized.

Agricultural cycles and seasonal labor are not incorporated into the design of learning rhythms. These issues collectively result in rural students being unable to obtain an online learning experience of the same quality as urban students even when they have access to technology, leading to inequity in the educational process. At the level of education outcome equity, research based on the multidimensional manifestations and empirical analysis of the digital divide found that low-income countries score higher across all three divides of the digital divide (78.6-85.7 points), and this shows a trend of increasing with each subsequent layer. From the first divide to the third divide, the score increases by 7.1

points, indicating that the digital divide has a cumulative effect, where disadvantages in the early stages are amplified in subsequent stages. High-income countries present a completely different picture, with lower scores across all three divides (12.4-22.3 points) and a more gradual change. This finding poses a profound challenge to educational equity—even if access and usage barriers are overcome, rural students still struggle to achieve the same educational outcomes as urban students. The digital divide ultimately translates into a gap in educational attainment, affecting rural students development opportunities and potential for social mobility.

The study also reveals that the expansion of online education has not automatically narrowed the digital divide. Despite global online education users growing from 860 million in 2019 to 2.12 billion in 2025, the penetration rate gap between high-income and low-income countries widened from 39.4 percentage points to 59.2 percentage points. The proliferation of mobile learning offers an opportunity to bridge the gap, but device affordability and network coverage remain major obstacles. Core Conclusions, the impact of the digital divide on educational equity is comprehensive and multi-layered. The access gap leads to unfairness in the starting point of education, the usage gap leads to unfairness in the educational process, and the effectiveness gap leads to unfairness in educational outcomes. These three gaps overlap and amplify each other, forming a structural dilemma for the development of online education in rural areas. To achieve educational equity under the digital divide, it is necessary to make coordinated efforts in multiple dimensions, including infrastructure investment, teacher capacity building, and localization of educational content, to ensure that rural students are not only able to“access”online education, but can also“ effectively participate”and have the opportunity for“equitable development”.

4.2. Research Limitations

This study has several limitations. Data capabilities in rural areas of developing countries are limited, and some data are based on estimations and projections, which may deviate from the actual situation. The research scope focuses on Sub-Saharan Africa and South Asia, and the general applicability of the conclusions needs to be treated with caution. The research method primarily relies on literature analysis and secondary data analysis, lacking in-depth field research.

Additionally, this studys response to the connotation of educational equity mainly focuses on the three dimensions of starting point, process, and outcome, with relatively limited discussion on other aspects of educational equity (such as education quality equity, education choice equity, etc.).

4.3 Future Prospects

Future research should further deepen the understanding of educational equity issues under the digital divide. Theoretically, it is possible to explore the more nuanced mechanisms of interaction between the digital divide and educational equity, especially the differential impacts of different types of digital divides on various dimensions of educational equity. Empirically, in-depth case studies of specific countries or regions can be conducted to obtain first-hand data to compensate for the limitations of secondary data. At the policy level, successful cases of bridging the digital divide and promoting educational equity can be studied to extract replicable experiences. At the technical level, the potential impacts of emerging technologies such as low earth orbit satellite internet on rural online education can be explored. The ultimate goal is to construct a systematic intervention strategy that takes into account education starting point equity, education process equity, and education outcome equity, allowing digital technology to truly become a lever for promoting educational equity, rather than a tool for exacerbating inequality.

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