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Digital Infrastructure, Educational Information Systems, and Inequality in Primary Learning Outcomes: Evidence from Sierra Leone

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Abstract

Digital technologies are increasingly promoted as tools for improving educational quality, yet unequal infrastructure, limited connectivity, and inadequate teacher preparation may constrain their effective use in resource-constrained settings. This study examines digital infrastructure and educational information system (EIS) readiness in government and government-assisted primary schools in Sierra Leone, situating digital inequality within digital divide theory and the DeLone and McLean information systems success model. A cross-sectional quantitative survey was conducted in 320 primary schools across all 16 districts, involving 640 teachers and 1,280 pupils (1,920 respondents). Data were collected through structured face-to-face interviews and school-level observations of digital infrastructure. Descriptive analysis revealed substantial constraints on digital readiness: approximately 90% of surveyed schools lacked computer laboratories, only 4% had internet-connected computer laboratories, and 97% of teachers reportedly had not received educational technology training. Electricity availability also varied across the five regions, indicating an uneven distribution of an essential enabling resource. These findings suggest that digital inequality in Sierra Leone's primary education system extends beyond physical access to encompass connectivity and teachers' preparedness to integrate technology into instruction. The study highlights the need for coordinated investment in reliable electricity, functional computing facilities, appropriate internet connectivity, curriculum-aligned offline and online resources, and sustained teacher professional development. By integrating digital divide theory with an information systems success framework, the study provides a context-sensitive basis for investigating the relationships between digital infrastructure, EIS quality, meaningful technology use, and foundational learning.

Keywords: Digital divide; educational information systems; digital infrastructure; teacher competence; foundational learning; primary education; Sierra Leone.

Introduction

Foundational literacy and numeracy remain major challenges in low- and middle-income countries (LMICs), with learning poverty estimated to affect approximately 70% of ten-year-olds following the COVID-19 disruptions (Bank, 2022). While digital technologies including educational applications and educational information systems (EIS) are widely promoted as means of improving teaching, accessing educational resource and school management, evidence increasingly indicates that these benefits are neither automatic nor evenly distributed. However, evidence suggests that their effectiveness depends on

the contextual, implementation and equitable access rather than technology alone (*2023 Global Education Monitoring Report, Technology in Education*, n.d.; Di Pietro & Castaño Muñoz, 2025). Sierra Leone faces substantial barriers to digital education. According to the 2022 Annual School Census, 75% of schools lacked electricity, rising to 85% of primary schools. Furthermore, almost all pupils in public primary schools attended schools without computers or internet access for teaching and learning (MBSSE, 2023). Limited electricity and internet access in various regions further lead to the constrain in the adoption of digital learning technologies, in schools. While Sierra Leone has set national education priorities and developed a National Digital Learning Strategy, successful implementation relies on empirical evidence regarding how school infrastructure, EIS availability, system quality, and the meaningful use of technology impact learning outcomes.

This study addresses the need for a comprehensive analysis of digital education in Sierra Leone by examining 320 government and government-assisted primary schools across all 16 districts. The data was collected from both teachers and pupils. The study makes three main contributions. First, it integrates digital divide theory with the information systems success model to explore the relationship between digital access, system quality, meaningful use, and learning outcomes. Second, it combines information reported by teachers and observed conditions in schools with pupil-level literacy and numeracy indicators. This approach helps reduce common-source bias and better investigates inequalities in learning. Third, it provides geographically diverse evidence to inform digital education policy in Sierra Leone. The study addresses four research questions: (1) What are the differences in digital infrastructure and the availability of Educational Information Systems (EIS) across districts, as well as between urban and rural schools and varying resource levels? (2) How do infrastructure and EIS availability relate to system quality and meaningful use? (3) What are the associations between meaningful EIS use and pupils' literacy and numeracy, including the moderating role of teacher competence? (4) How do these relationships and learning inequalities vary across different school contexts, including the extent to which learning variation can be attributed to differences between schools?

Importantly, the study employs a cross-sectional quantitative design and therefore identifies conditional associations rather than causal effects. Its findings are intended to strengthen the evidence base for equitable digital learning policies and guide future research using qualitative and longitudinal approaches.

Review of Related Literature

The theory of the digital divide has evolved from focusing solely on physical access to addressing inequalities in digital skills, usage, and outcomes(Albakri & Wood-Harper, 2025; Lythreatis et al., 2022). Research indicates that digital exclusion exacerbates existing social inequalities (Helsper, 2021) and continues to be a challenge in educational settings across sub-Saharan Africa (Constancio, 2025). In primary education, simply having access to devices does not ensure effective technology use or improved learning outcomes. Factors such as teachers' digital competencies, institutional support, and curriculum-aligned content are equally crucial. This study therefore conceptualizes digital inequality across three dimensions: access to infrastructure, utilization of meaningful educational information systems, and students' learning outcomes.

The information systems success model in educational settings.

The DeLone and McLean model conceptualizes information systems success through interconnected dimensions of system quality, information quality, service quality, use, user satisfaction, and net benefits.

In primary education, these dimensions encompass system reliability, curriculum-relevant content, teacher training, technical support, and effective classroom integration. However, inconsistencies in empirical operationalization highlight the need for context-specific adaptations (Jami Pour et al., 2022; Jeyaraj, 2020; Sabeh et al., 2021). Accordingly, this study adapts the model to educational information systems available in schools, measuring meaningful use separately from pupil learning outcomes. Teacher-reported satisfaction is treated descriptively, while pupil-level literacy and numeracy indicators assess educational benefits independently. Crucially, the study distinguishes physical infrastructure, including electricity, connectivity, and devices, from system quality, examining EIS availability first and system quality among schools where such systems exist.

Educational technology and learning in LMICs.

Research from low- and middle-income countries (LMICs) shows that educational technology can lead to modest but positive learning improvements, which depend on how it is implemented and the pedagogical methods used (Di Pietro & Castaño Muñoz, 2025). Research consistently indicates that simply providing technology has limited effects on learning outcomes. In contrast, methods such as computer-assisted learning, personalized instruction, and ongoing teacher training show much greater potential for improvement. Additionally, meta-analytic evidence suggests that adaptive learning software can enhance learning outcomes, especially when the instruction is tailored to match students' abilities (Evans & Popova, 2016; Yeung et al., 2021). However, the effectiveness of digital interventions depends on content quality, teacher professional development, and sustained classroom integration, and the evaluations of educational technology in LMICs also emphasise equity, affordability, implementation context, and scalability(Nicolai et al., 2023; Norman, 2023).

These findings examining the importance of evaluating the quality of educational information systems, the meaningful use of technology, and teacher competence instead of assuming that simply having access to infrastructure is enough to enhance learning. However, there is limited evidence on how schools' current digital resources relate to learning outcomes, especially in real-world conditions with infrastructure limitations. This study addresses this gap through a cross-sectional analysis focused on Sierra Leone.

National context.

Sierra Leone has expanded primary school enrolment through the Free Quality School Education programme, yet foundational literacy and numeracy remain weak(Mullan & Abeba Taddese, 2020). Digital inequality compounds these challenges, as 85% of primary schools lacked electricity in 2022, particularly affecting pupils in public schools (MBSSE, 2023). Despite expanding mobile infrastructure, internet use and school connectivity remain limited, restricting opportunities for digital learning (Kemp, 2025). The National Digital Learning Strategy identifies unequal device access, unreliable connectivity, limited digital skills, and inadequate locally relevant content as persistent barriers (Marina Samardzija, 2025)(Waziri et al., 2025). In response, government and partner-supported initiatives are introducing offline-first, solar-powered digital learning resources to overcome infrastructure constraints (Lurvink & Pitchford, 2023). However, differences in programme support, school resources, and teacher capacity highlight the need to examine digital readiness and educational information system use across schools. This study addresses these challenges by investigating how infrastructure and educational information systems relate to learning outcomes and educational inequality in Sierra Leone’s primary schools.

Research gap

Three gaps follow. First, evidence on the conditions under which school digital resources are associated with learning in Sierra Leone is thin: existing national work is descriptive of access (MBSSE, 2023)(Mullan & Abeba Taddese, 2020) or qualitative and intervention-specific (Lurvink & Pitchford, 2023), and work on information systems has concentrated on management systems rather than on systems that support instruction (Kaindaneh et al., 2024). Second, studies seldom test the full chain from infrastructure through system quality and use to measured learning, or examine how teacher competence and school context condition it; a review of the sub-Saharan literature notes uneven representation of subjects, regions and groups (Constancio, 2025). Third, inequality is usually described by comparing group means, whereas the distribution of learning and the share of variation lying between schools are rarely examined. This study addresses these gaps.

Conceptual model and propositions:

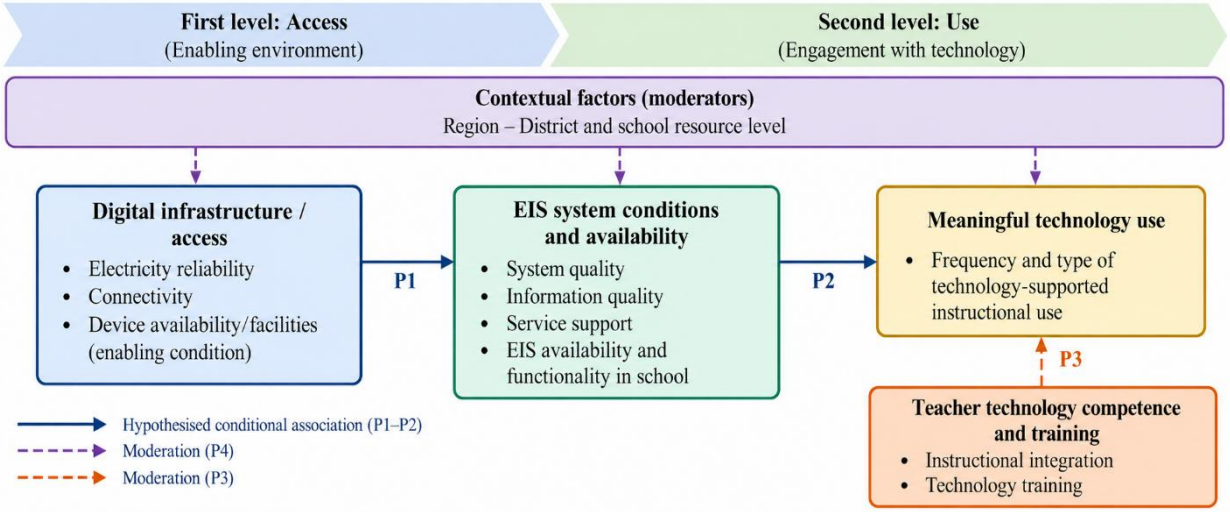


Figure 1 Conceptual Framework for Examining Digital Technology Use and Foundational Learning Outcomes in Primary Schools

Figure 1 presents the conceptual framework guiding the examination of the relationships between digital infrastructure, educational information system (EIS) success, technology use, and foundational learning outcomes in primary education. The framework proposes a sequential pathway through which access to digital resources may support effective educational technology use and, in turn, contribute to pupils' literacy and numeracy development.

Digital infrastructure, comprising electricity reliability, internet connectivity, and device availability, represents the foundational enabling condition for EIS availability and functionality in schools. In this study, EIS refers to digital systems that support teaching, learning, or assessment, including tablet-based learning applications, downloaded or offline educational content, and digital school data tools used by teachers. The framework recognizes that infrastructure availability alone may not ensure effective educational technology use; its potential benefits also depend on the quality and functionality of the systems available.

EIS success is represented by three interrelated dimensions: system quality, information quality, and service support. System quality concerns the reliability and usability of digital systems, information quality refers to the relevance and accuracy of their educational content, and service support encompasses

the technical assistance and guidance available to teachers. These dimensions are expected to be associated with meaningful EIS use, defined in terms of the frequency, duration, and instructional purposefulness of technology use during teaching and pupil practice. Meaningful use is, in turn, expected to be associated with foundational learning outcomes, particularly pupils' literacy and numeracy.

Teacher competence is incorporated as a potential moderator of the relationship between meaningful EIS use and learning outcomes. It reflects teachers' capacity to integrate digital resources into instruction in ways that support curriculum delivery, pupil engagement, and learning activities. Accordingly, the relationship between technology use and learning outcomes may vary according to teachers' competence in instructional integration.

The framework further incorporates region–district location and school resource level as contextual moderators that may influence the strength of the proposed relationships. Differences in local conditions and school resources may shape infrastructure availability, EIS functionality, patterns of technology use, and the extent to which such use is associated with learning outcomes. Pupil and household characteristics, prior achievement, teacher qualifications, and class size are identified as potential confounding variables and will be controlled for where suitable data are available.

Overall, the framework provides a basis for examining how enabling infrastructure, EIS quality, meaningful technology use, teacher competence, and contextual conditions are associated with foundational learning outcomes. Because the proposed relationships are examined within a cross-sectional design, the framework specifies hypothesised associations rather than causal effects.

Where:

P1: Infrastructure and EIS success: Examines whether more reliable electricity, connectivity, and device availability are associated with better EIS availability and functionality.

P2: EIS success and meaningful use: Examines whether system quality, information quality, and service support are associated with more frequent and instructionally purposeful technology use.

P3: Meaningful use and learning outcomes: Examines whether meaningful technology use is associated with stronger foundational literacy and numeracy.

P4: Teacher competence: Examines whether teacher competence moderates the relationship between meaningful use and learning outcomes.

P5: Contextual moderation: Examines whether region–district location and school resource level modify the strength of the proposed relationships.

Methodology

The study is a cross-sectional survey using structured questionnaires administered to teachers and pupils in sampled schools. It estimates conditional associations between school digital infrastructure, EIS quality and use, and pupils' foundational literacy and numeracy (Setia, 2016).

The setting is Sierra Leone, which consists of 16 districts. The target population is the government and government assisted primary schools in Sierra Leone, that is, government and government-assisted primary schools with Grade 4-5 classes. In the Annual School Census, government schools are those constructed and wholly owned by the central government or local councils, and government-assisted schools are public schools owned by faith-based organizations or communities (MBSSE, 2023). Private schools and public schools (not approved by government) not receiving government support were outside the target population.

The sample was allocated equally across the 16 districts. In each district, 20 schools were sampled using simple random sampling from the district list, giving 320 schools. In each school, 2 teachers and 4 pupils were interviewed: one teacher from grade 4 and one teacher from grade 5; pupils were drawn at random from the class register. The sample therefore comprises 640 teachers, 1,280 pupils and 1,920 respondents in total, or 120 respondents per district as shown in Table 1. Schools were eligible if they were government or government-assisted and had an enrolled Grade 4 and 5 classes; schools were excluded if they were private, were public but not government-supported, or were inaccessible for logistical or security reasons. The school response rate was 99.5%, and the respondent response rate was 99.5%. Fieldwork took place from 7th January, 2026, to 30th April, 2026; enumerators were trained for five days and data were collected in English.

Table 1. Distribution of Respondents

Unit	Per school	Per district schools	National / districts
Schools	1	20	320
Teachers	2	40	640
Pupils	4	80	1,280
All respondents	6	120	1,920

Data were collected with two structured questionnaires administered by trained enumerators in face-to-face interviews. School-level conditions were reported by the sampled teachers and verified by enumerator observation of electricity, devices and connectivity on the day of the visit; EIS availability, use and teacher competence were reported by teachers; and learning indicators and school characteristics were collected from the selected pupils. Using different respondent groups for exposures and outcomes reduces common-source bias.

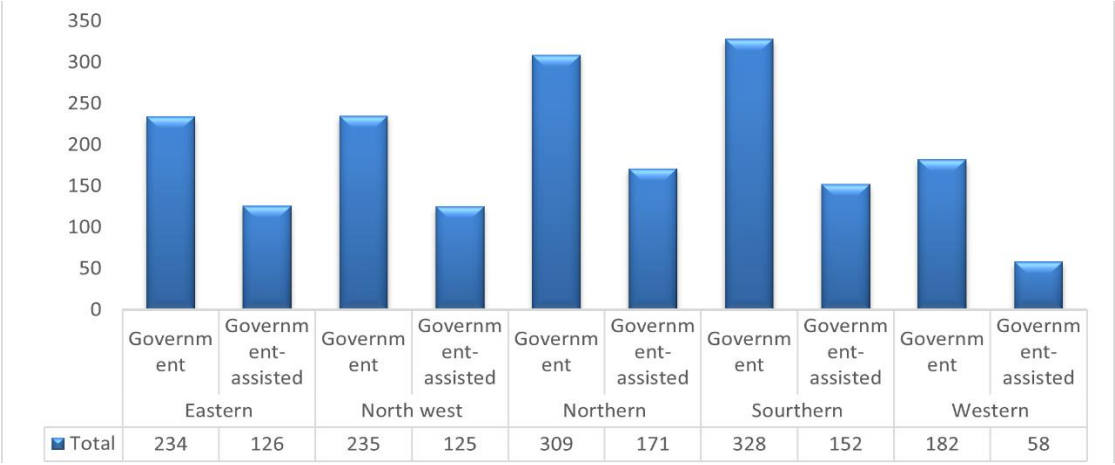
Result:

Table 2. Distribution of Respondents by School Ownership and Sex

School Ownership	Female	Male	Total
Government	522	766	1288
Government Assisted	227	405	632
Total	749	1,171	1920

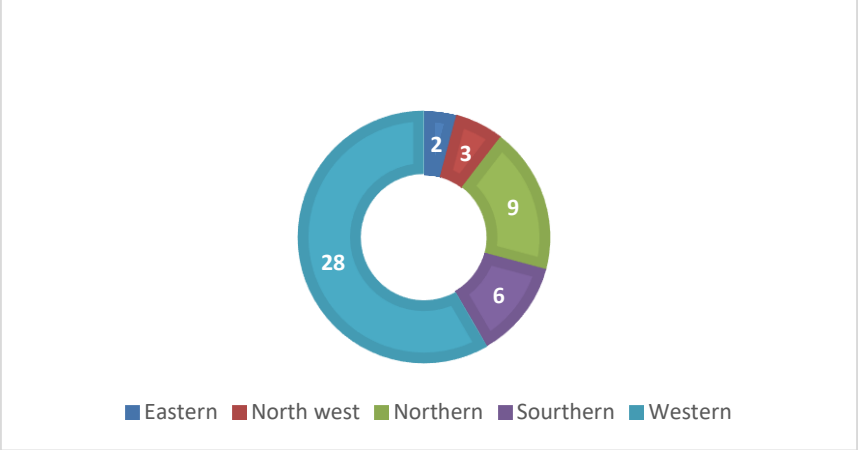
The study included 1,920 respondents, comprising 749 females (39.01%) and 1,171 males (60.99%). Government schools accounted for 1,288 respondents (67.08%), while government-aided schools accounted for 632 (32.92%). In both school ownership categories, male respondents outnumbered female respondents.

Figure 2: Regional Distribution of Schools by Ownership Type



The regional distribution of schools revealed variations in the representation of government and government-aided schools across the five regions. The Southern region recorded the highest number of government schools (328), followed by the Northern (309), North Western (235), Eastern (234), and Western regions (182). Government-aided schools were most numerous in the Northern region (171), followed by the Southern (152), Eastern (126), North Western (125), and Western regions (58). Overall, government schools outnumbered government-aided schools in every region. The difference was particularly pronounced in the Western region, where government schools accounted for 182 compared with 58 government-aided schools. These findings indicate that the school sample was predominantly drawn from government schools, although the extent of representation varied across regions. The Western region had the lowest counts for both ownership categories, whereas the Southern region recorded the highest number of government schools.

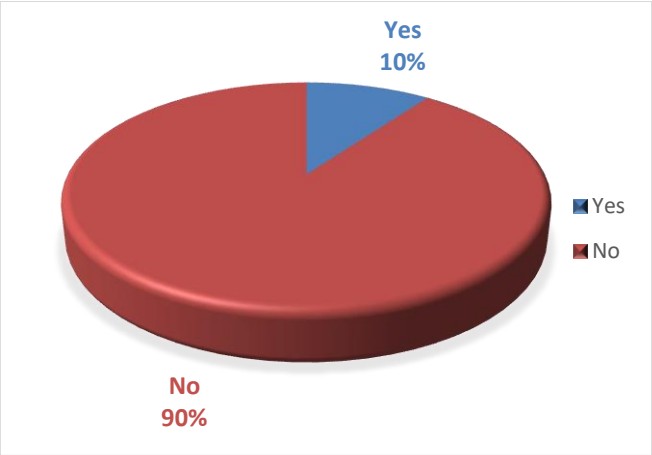
Figure 3: Regional Distribution of Electricity Availability Across the Study Areas



The regional distribution of electricity availability varied considerably across the five regions. As shown in Figure 3, the Western region accounted for the largest share at 58%, followed by the Northern region at 19% and the Southern region at 13%. The North Western region represented 6%, while the Eastern region recorded the lowest share at 4%. These findings indicate an uneven regional distribution of electricity availability across the study areas, with the Western and Northern regions together accounting

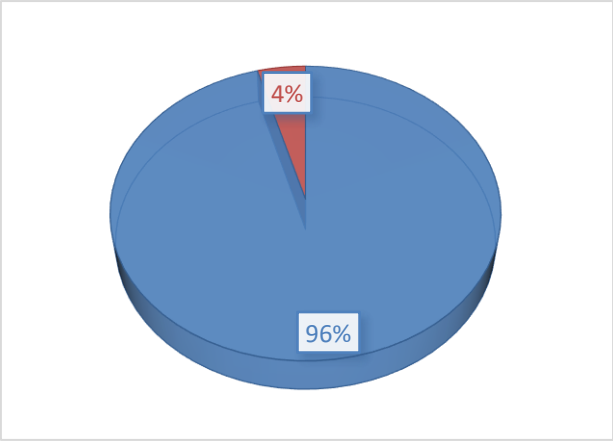
for 77% of the reported distribution. This variation highlights the importance of considering regional differences when examining digital infrastructure and the potential for integrating educational information systems into primary schools.

Figure 4: Availability of Computer Laboratories in the Surveyed Schools



The findings indicate a substantial disparity in computer laboratory availability across the surveyed schools. As shown in Figure 3, 90% of schools reported having no computer laboratory, while only 10% reported having computers. This pattern suggests that dedicated computer laboratory facilities are limited within the study sample, potentially constraining access to digital resources and opportunities for technology-supported teaching and learning. The findings highlight the importance of strengthening school-level digital infrastructure to support the effective integration of educational information systems into classroom practices.

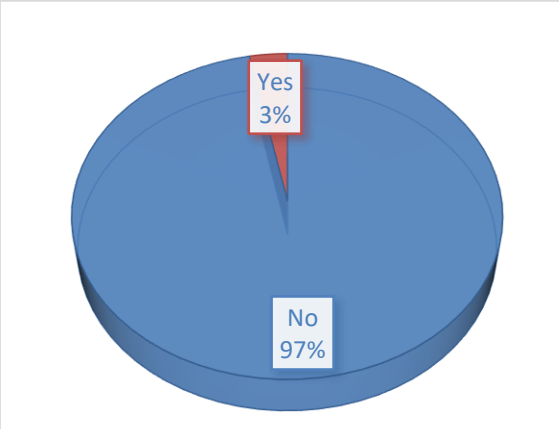
Figure 5: Availability of Internet-Connected Computer Laboratories in the Surveyed Schools



The findings reveal a substantial digital infrastructure gap across the surveyed schools. As shown in Figure 7, only 4% of schools had computer laboratories with internet connectivity, whereas 96% had computer laboratories without internet access. This disparity suggests that the availability of computer laboratories does not necessarily ensure internet-enabled digital learning opportunities. Limited connectivity may constrain teachers' access to online educational resources and the effective implementation of educational

information systems. These findings highlight the need for integrated investments in computer facilities and reliable internet connectivity to strengthen technology-supported teaching and learning.

Figure 6: Teachers' Training in Educational Technology



This shows that 97% of teachers had not received training in educational technology, whereas 3% had receive educational training. As illustrated in Figure 6, the high reported lack of training coverage suggests that most teachers do not have preparation for using technology in education.

Discussion

The descriptive findings indicate substantial constraints in digital readiness among the surveyed primary schools, with approximately 90% lacking computers, 96% lacking internet connectivity, and 97% reporting no teacher training in technology. These patterns suggest that digital disadvantage encompasses infrastructure access, connectivity, and teachers' capacity to integrate technology into instruction. Although limited digital resources may constrain access to technology-supported learning, offline educational applications and locally stored content offer potential alternatives. The reported lack of teacher training further highlights the importance of developing pedagogical and technical competencies alongside infrastructure provision. Regional distributions also reveal differences in sample representation, with the Northern and Southern regions each accounting for approximately 25% of the surveyed schools, the Eastern and the Northwest region each accounting for 18.75 of the surveyed schools and the Western region 12.5%. However, these descriptive patterns should be interpreted cautiously and do not independently establish regional differences in digital access or learning outcomes.

Relation to previous research

The findings align with digital divide theory, which conceptualises digital inequality through differences in technology access, digital skills, usage, and outcomes (Albakri & Wood-Harper, 2025, 2025; Lythreatis et al., 2022). Limited computer availability, internet connectivity, and teacher training highlight the need to address these dimensions jointly in Sierra Leone's primary schools. The findings also reflect the DeLone and McLean (2003) information systems success model, which emphasises system quality, information quality, service support, meaningful use, and educational benefits. Existing research reinforces the importance of context-specific measurement and cautions against assuming that technology access automatically produces beneficial outcomes(Jeyaraj, 2020; Sabeh et al., 2021). Consistent with (UNISCO, 2023), effective digital education depends on appropriate educational content, teacher

competencies, reliable infrastructure, technical support, and equitable access to technology. These findings align with Sierra Leone's digital learning priorities, which emphasise strengthening digital infrastructure, enhancing teachers' capacities, and expanding inclusive access to technology-supported learning (Marina Samardzija, 2025), but further statistical analysis is necessary to establish whether digital readiness is associated with pupils' learning outcomes.

Implications for Policy and Practice

The findings highlight the need for an integrated approach to digital education in Sierra Leone, addressing infrastructure, teacher competencies, and curriculum-aligned digital content simultaneously.

Policymakers should prioritize access to functional computers, reliable electricity, and affordable internet access while considering offline learning resources in areas with limited connectivity. Teacher professional development should focus on both technical skills and the effective pedagogical use of digital technologies, supported by continuous training and practical assessment.

Furthermore, digital education investments should be guided by verified school-level needs, taking into account geographic location, existing resources, and maintenance costs. Monitoring and evaluation should extend beyond the provision of devices and training to assess technology utilization, educational equity, and improvements in pupils' literacy and numeracy outcomes. This integrated, evidence-based approach can help ensure that digital education initiatives expand meaningful learning opportunities and reduce inequalities across schools in Sierra Leone.

Conclusion

This study highlights the interconnected nature of digital infrastructure and educational information systems (EIS) as dimensions of digital inequality in Sierra Leone's primary education system. The descriptive findings reveal persistent challenges in internet connectivity, the availability and functionality of computers, teacher preparedness, and school-level technical support. These constraints indicate that access to digital resources must be complemented by relevant educational content, continuous professional development, equipment maintenance, and adequate technical assistance. By integrating digital divide theory with the DeLone and McLean information systems success model, the study provides a conceptual basis for examining how technological access, system quality, and meaningful use may shape educational opportunities. Further empirical analysis is needed to establish whether these dimensions of digital readiness are associated with pupils' foundational literacy and numeracy outcomes. Addressing digital inequality therefore requires a coordinated, context-sensitive, and evidence-based approach that promotes equitable access and measurable improvements in educational outcomes.

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